THE CHEMICAL RESISTANCE OF ALUMINIUM MATERIALS OF DIFFERENT COMPOSITION IN CONCRETE, MORTAR AND GYPSUM*

By

G. J. V. JAGANNADHA RAJU and A. DOMONY

The building industry requires increasing amounts of aluminium — apart from the "classical" uses as roof covering, scaffolding tubes, leaf and framework of gap closing devices, indoor banisters and decorating parts, — primarily as a prefabricating element (wall-element) of industrial and residential buildings, for the building of small cottages for permanent use and for those which can be dismantled, for covering of vast areas without inside support, etc.

In spite of the fact that the durability of aluminium and its chemical resistance against various atmospheric conditions can be considered as an universally recognized fact [1] the behaviour of light metals in relation to building materials has only been investigated in the last years.

As a matter of fact, most of the building materials (especially the concrete and the mortar) are of alkaline character (pH = 11—13) and as a result of this, up to about 1950 the related scientific literature was unanimous in calling for a protection by a bituminous or other coating of light metals in contact with building materials to avoid corrosion.

TRONSTAD and VEIMO were the first to show in 1939 [2] after experiments of 1.5 years duration, that apart from the first period of attack, the corrosion of 99.6% aluminium, even in highly corrosive building materials, is not as serious as it was believed to be previously. They have equally shown that an artificial thickening of the oxide film (by chemical or anodic oxidation) does not result in an increase in the resistivity of samples embedded in building materials, in a dry and humid atmosphere. Their results are shown in Fig. 1.

As a result of TRONSTAD's and VEIMO's researches further detailed investigations were carried out to determine the corrosion resistance of aluminium against building materials in Germany by FISCHER and VOSSKÜHLER [2], and in the United States by WALTON and his associates [3] in the last five years. These investigations have proved that the highly corrosive alkaline building

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materials, after an initial quick corrosion, are not detrimental for the light metals. The results of the detailed work of WALTON and co-workers are summarised in Table 1.

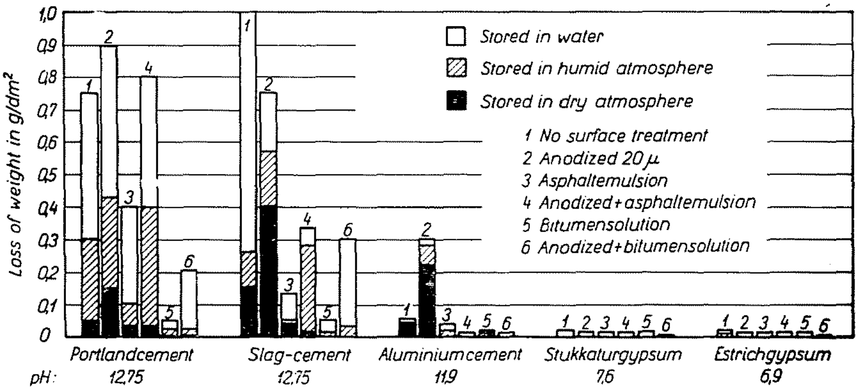

Fig. 1. Weight loss of 99.6% Al in different building materials after 1.5 years of exposure. (According to TRONSTAD-VEIMO). [1]

Table 1

The degree of corrosion in various aluminium materials embedded into concrete as a function of time, according to Walton and co-workers [3]

Duration of corrosion	Type of alloy	Average depth of corrosion micron	Max. depth of corrosion micron
1 hour	Al-1.2% Mn	0—2.5	10.2
6 hours	Al-1.2% Mn	2.5	10.2
24 hours	Al-1.2% Mn	2.5	10.2
9 days	Al-1.2% Mn	10.2	17.8
28 days	Al-1.2% Mn	15.2—22.8*	33.0—38.1*
60 days	Al-1.2% Mn	2.5—10.2*	12.7—27.9*
90 days	Al-1.2% Mn	73.6*	109.2*
6 months	Al-1.2% Mn	5.1—45.72*	15.2—109.2*
8 years (stored in laboratory)	Al-1.2% Mn	43.2	127.0
8 years (stored in industrial atmosph.)	Al-Mg-Si	48.2	96.5
8 years (stored in seaside atmosphere)	Al-Cu-Mg-Mn	60.9	111.8
27 years (stored in industrial atmosph.)	Al-Si	35.5	104.2
27 years (stored in seaside atmosphere)	Al-Mg-Si	35.5	66.0

Note: the samples marked * were stored in humid atmosphere during the whole test period.

The results of the investigations on the behaviour of aluminium against concrete, mortar and lime — so far published — are in general agreement, but were not extended to clarify the role of the purity of the metal and to determine the velocity of corrosion of metals of different purities. So an attempt is made to investigate the behaviour of different sorts of aluminium in concrete, in mortar and in gypsum. Part of the samples bearing strengthened oxide layer were boehmitized (by boiling for 3 hours in distilled water), while another set of them was conventionally treated by the MBV processes (oxidizing bath: 5% soda, 1.5% potassium bichromate, boiling for 30 minutes, rinsing, then final sealing by boiling for 30 minutes in tap water), a third group was anodized (for 40 minutes in a 12% H_2SO_4 bath with d. c. at 22° C, then sealed by boiling for 30 minutes in water).

The designation and composition of materials used in experiments are listed in Table 2.

I. The investigation of aluminium materials in concrete

I/1. *The corroding effect of concretes of different composition on aluminium materials*

The test pieces were rods of 10 mm diameter (except for the Al—Zn—Mg alloy samples which were of 5 mm diameter), the strength and composition of which can be seen in Table 2.

The rods of 250 mm length each were embedded into concrete cubes of 20 × 20 × 20 cm size, according to the following grouping, in such a way. that about 50 mm of their length was outside the cube.

The composition and conditions of storing the concrete cubes was as follows: the test samples, marked 1—8 were prepared from cement marked 500 of Lábatlan (CaO = 64,3%) of 430 kg/cm^3 using a 0.44 water-cement factor. The samples marked 1 to 3 and number 7 were stored in dry atmosphere while those marked 4, 5, 6, 8 received additional wet treatment (with ample supply of water every third day). The materials embedded into test-pieces marked 3, 4, 5 were investigated after 3 months duration, while those marked 1, 2, 6, 7 and 8 were tested after six months.

The test-piece marked 9, was a cement-mortar cylinder comprising 1 part by weight of cement, 1 part of gravel and 0.86 part of water. It was stored in dry atmosphere and was tested after 6 months.

The composition of samples, marked 10, 11, 12 was identical with those marked 1 to 8, except that they were prepared with a 1.5% sodium bichromate addition. Test-pieces marked 10 and 11 were stored in dry atmosphere, while that of No. 12 received additional wet treatment. Duration of the test was 6 months.

The samples marked 13 and 14 were made from cement marked 500 of Tata (CaO : 60.2%) of 430 kg/m^3 using 0.44 water-cement factor. No. 13 was

Table 2

The composition and strength characteristics of aluminium test samples used in our corrosion experiments

Designation of the rod	Composition in %					Strength characteristics		
	Fe	Si	Cu	Mg	Zn	σ 0.2 kg/mm²	σ_B kg/mm²	δ%
99.99% Al	0.003	0.002	0.002	0.001	0.001	3.0	5.3	46
99.99% Al + 0.05% Fe	0.05	0.003	0.002	0.001	0.001	3.0	4.5	40
99.99% Al + 0.10% Fe	0.10	0.003	0.002	0.001	0.001	3.0	6.4	46
99.99% Al + 0.25% Fe	0.26	0.004	0.002	0.001	0.001	3.2	7.4	48
99.99% Al + 0.75% Fe	0.76	0.004	0.002	0.001	0.001	4.1	8.0	46
99.99% Al + 0.25% Fe + 0.25% Si	0.25	0.25	0.002	0.001	00.01	4.0	7.4	36
99.99% Al + 0.05% Si	0.004	0.05	0.002	0.001	0.001	3.7	6.1	40
99.99% Al + 0.25% Si	0.004	0.25	0.002	0.001	0.001	5.7	7.7	27
99.99% Al + 0.75% Si	0.005	0.75	0.002	0.001	0.001	5.4	8.2	25
99.99% Al + 1.5% Si	0.007	1.55	0.002	0.001	0.001	7.7	9.5	21
99.99% Al + 1.75% Si	0.007	1.74	0.002	0.001	0.001	5.9	8.9	52
99.99% Al + 2.5% Si	0.008	2.50	0.002	0.001	0.001	5.3	9.1	34
A*	0.25	0.14	0.01	0.001	0.035	6.6	9.3	29
B*	0.22	0.64	0.01	0.50	—	10.5	19.3	19
H*	0.20	0.20	0.01	2.60	3.40	30.2	35.6	7
D	0.18	0.15	3.80	0.82	—	28.6	43.0	10
E	0.20	0.20	0.01	2.60	5.46	27.6	45.0	8
Strips								
N	0.003	0.002	0.002	0.001	0.001			
Mg	0.005	0.002	0.002	0.80	0.001			
A	0.25	0.14	0.01	0.01	0.035			
B	0.22	0.64	0.01	0.50	—			

Note: The diameter of the rods was 10 mm, except for the sample marked H* where it was 5 mm. The Mn-content of sample D was 0.60% and of sample E 0.29%. The thickness of the bands was 0.12 mm. The samples marked* were tested in concrete samples in original state and after by three types of surface treatments.

kept in a dry atmosphere, while No. 14 received wet treatment. Duration of the test was 6 months.

The aluminium rods coloured red and green resp. were embedded into a perlite-concrete cube.

After the given time of storage the cubes were crushed in the hydraulic press at the Institute of Building Materials. The concrete, sticking to the aluminium, was removed with a hammer before investigation.

a) *General findings*

1) The strength of concrete was not changed by embedding aluminium rods into it. This was proved by the fact that the force required to crack the concrete cubes was — according to the information of the research workers of the above referred Institute — equal to that needed to crack similar cubes of reinforced concrete.

2) The sticking of aluminium to concrete can be considered as excellent and according to the estimations it was better than that of iron. This sticking of aluminium was found to be independent of the composition of aluminium and the surface treatment of the samples. To get numerical values for its characterisation it is intended to make additional "outpulling" tests.

3) The artificial strengthening of the surface oxide layers whether to be done by boehmitizing, chemical oxidization or anodizing, did not change the corrosion resistance of the samples. The artificially strengthened oxide layer is dissolved at the influence of the concrete and thus cannot protect the metal below it.

4) Except for refined (high purity) aluminium and 99.5% aluminium no detectable major attack was to be found at the concrete-air interface.

b) *Detailed experimental results*

The investigation of the surface of the samples embedded in cement of Lábatlan and stored in dry atmosphere (marked 1, 2, 3, 7) have revealed the results in Table 3.

From the detailed inspection of the surfaces it can be stated:

1) The strongest corrosion could be observed on the surface of the refined 99.99% aluminium.

2) Alloying of both Fe and Si to refined aluminium decreases the degree of pitting.

3) The character of attack on the surface of virgin aluminium (sample, marked "A") is the same as that of high purity aluminium alloyed with 0.25%, 0.75% Fe or 0.75% Si respectively.

4) For the alloy, marked "B", the depth of the corrosion "pits" is smaller than for virgin aluminium.

5) On the surface of the samples, marked "D", "E" and "H" there is a gray to black, well sticking layer. The depth of the pits is smaller for the alloy, marked "H" than with the other two alloys. The cavities — compared to those on high-purity aluminium — are relatively broader and for this reason they seem to have less steep walls.

6) On all the samples the character of changes in the surface were the same as the 3 and 6 months old samples.

Table 3

Designation	Decrease of diameter	
	in 3 months, mm	in 6 months, mm
99.99% Al	—	0.11
99.99% Al + 0.05% Fe	—	0.09
99.99% Al + 0.10% Fe	—	0.06
99.99% Al + 0.25% Fe	—	0.04
99.99% Al + 0.75% Fe	—	0.05
99.99% Al + 0.25% Fe + 0.25% Si	—	0.05
99.99% Al + 0.05% Si	—	0.10
99.99% Al + 0.25% Si	—	0.09
99.99% Al + 0.75% Si	—	0.05
99.99% Al + 1.50% Si	—	0.02
99.99% Al + 1.75% Si	—	0.03
99.99% Al + 2.5% Si	—	0.02
A	0.04	0.04
B	0.01	0.02
H	0.01	0.03
D	0.03	0.03
E	0.03	0.03

The cross-section of the test rods was investigated after embedding into dentacryle plastic and polishing them to find the average depth of the corrosion. Magnification was x 90. On Fig. 2 the surface corrosion of materials marked A, B, H, D and E were seen after 6 months' corrosion in concrete.

On measuring the average depth of corrosion on photographs, we get the values shown in Table 4.

Table 4

The average depth of corrosion after 3 months and 6 months on samples in contact with cement of Lábatlan, kept in dry atmosphere

(Measured at a magnification of $\times 90$, microscopically)

Designation	Average depth of corrosion mm	
	3 months	6 months
A	0.045	0.030
B	0.010	0.015
H	0.015	0.020
D	0.035	0.030
E	0.035	0.040

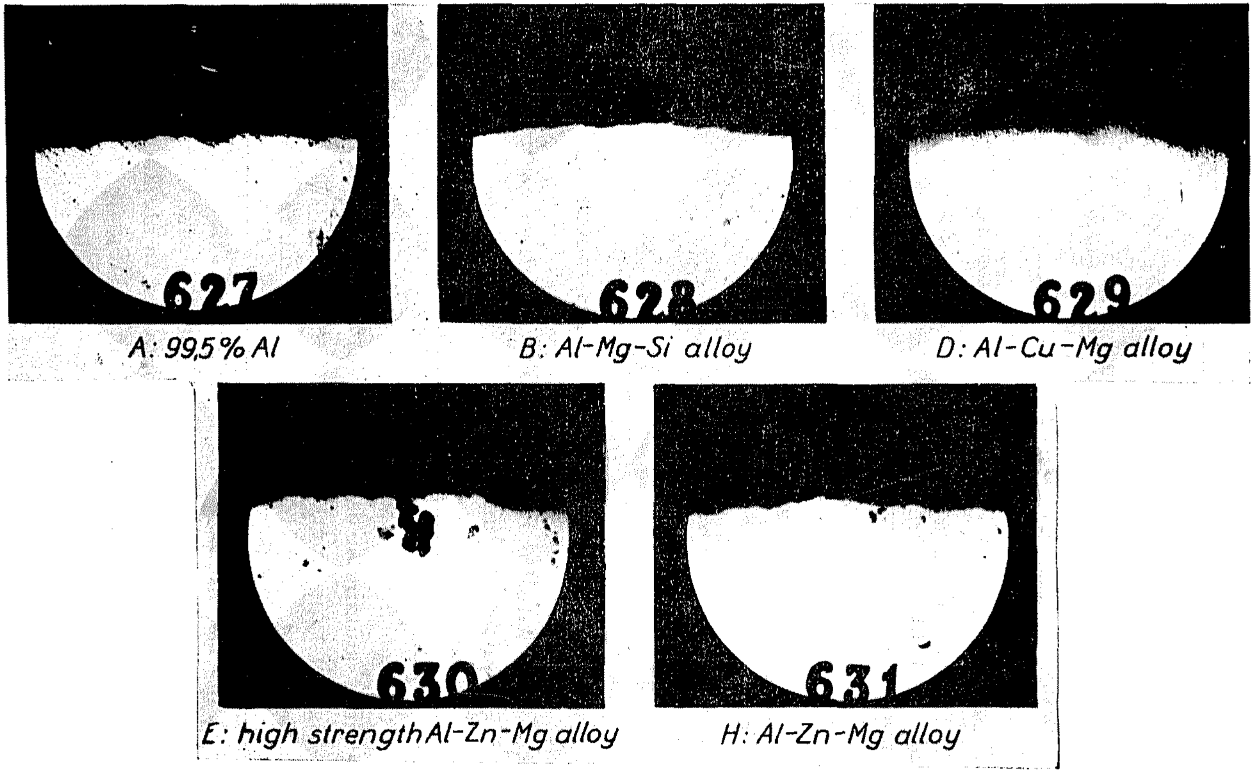

Fig. 2. Cross-section of aluminium rods embedded into concrete for 6 months. (× 90)
A: 99,5% Al
B: Al—Mg—Si alloy
D: Al—Cu—Mg alloy
E: high strength Al—Zn—Mg alloy
H: Al—Zn—Mg alloy

Comparing these results with those of decrease in diameter shown in Table 3, the agreement is found to be fairly good.

In Table 5 the results of the samples A, B, H, D, E after 6 months' corrosion in different concrete are compared.

Table 5

Decrease in mm of diameters of samples marked A, B, H, D, E after storing for 6 months in different concretes

Designation	Cement of Lábatlan (No of samples 1—8)		Cement of Lábatlan with 1.5% sodiumbichromate (No of samples 10, 11, 12)		Cement of Tata (No of sample 13, 14)		Cement mortar (No of sample 9)	Perlit-con-crete
	dry	humid	dry	humid	dry	humid	dry	dry
99.99 Al	0.11	—	—	—	—	—	—	—
A	0.04	0.06	0.03	0.04	0.01	0.04	0.01	—
B	0.02	0.03	0.01	0.02	0.03	0.03	0.01	—
H	0.03	0.05	0.04	0.05	—	0.04	0.02	—
D	0.03	—	0.03	—	—	—	—	—
E	0.03	—	0.03	—	—	—	—	—

The result of investigations with concrete are summarized below:

1) In accordance with the findings of foreign research workers we have found that the corrosion of aluminium materials embedded into concrete slackens after an initial attack of about 6 months and no more corrosion can be observed. The depth of corrosion depends on the composition of the metal and the type of the cement and varies between 0.01—0.10 mm.

2) High-purity aluminium is the most severely attacked by concrete. Alloys of Al—Mg—Si type (marked "B") were found to have the highest resistance. The degree of corrosion of virgin aluminium and of high-strength heat treated alloys is between the two mentioned extremes. The corrosion effect of concrete reveals itself in point or crater-like attack.

3) The degree of attack on aluminium slightly depends on the alkalinity of the cement as well. The perlite-concrete compared to normal cement is less aggressive against aluminium. The addition of bichromate inhibitor to the concrete — specially in the presence of moisture — slightly decreases the corrosion of aluminium.

4) The presence of moisture but slightly increases the corrosion of aluminium materials in concrete.

5) An artificial strengthening of the surface oxide layer of aluminium materials is of no value against the corrosion attack of concrete.

I/2. The rate of corrosion on aluminium materials of different purity due to the attack of concrete

In order to ascertain the rate of corrosion and the form of its appearance, strips of 0.1 mm nominal thickness from high-purity aluminium (marked "N"), of high-purity aluminium alloyed with magnesium ("Mg"), virgin aluminium ("A") and of Al—Mg—Si alloy ("B"), were made. The chemical composition of the strips is shown in Table 2. They were embedded into concrete cylinders of 150 mm long and of 110 mm diameter, in that way that part of the strips was outside the cylinders allowing for the inspection of the process likely to occur on the air-concrete interface. The concrete was made of cement marked 500 of Lábatlan of 430 kg/m^3 with 0.44 water-to-cement ratio. The concrete blocks were stored in dry atmosphere and were crushed after 1, 4, 6, 14, 24, 36, 48 and 60 days. The concrete stuck to the surface of aluminium bands was dissolved by dilute nitric acid followed by a phosphoric acid-chromic acid (35 cm^3/l phosphoric acid +20 g/l chromic acid) treatment. The metal-clear surface of aluminium bands was investigated under a microscope with 40 times magnification, especially to observe the changes on the air-concrete interface. In order to get the degree of pitting (hole-formation across the band) contact replicas were made. Furthermore, the decrease of the thickness of the bands by a micrometer and the change of the "bending number" of them were also measured.

Evaluation of the experimental results

On examining the surface of the samples it was found that the surface of high-purity aluminium (marked "N") was badly damaged even after storing for 24 hours and there were holes across it in several places. The diameter of corrosion cavities is wide and comprises vast areas. At the air-concrete interface the degree of attack is even more marked.

The surface of the high-purity aluminium alloyed with magnesium (marked "Mg") — apart from local scars — was even. There is no hole across the strip. The air-concrete interface was sound.

The surface of the virgin aluminium (marked "A") is attacked and it can be seen that at some points the holes began to form. The corrosion cavities were much smaller than those on the high-purity materials. The air-concrete interface was sound.

The surface unevenness of samples of Al—Mg—Si (marked "B") was about the same as that of the virgin aluminium, the only difference being that no holes across the band could be detected. The air-concrete interface was sound.

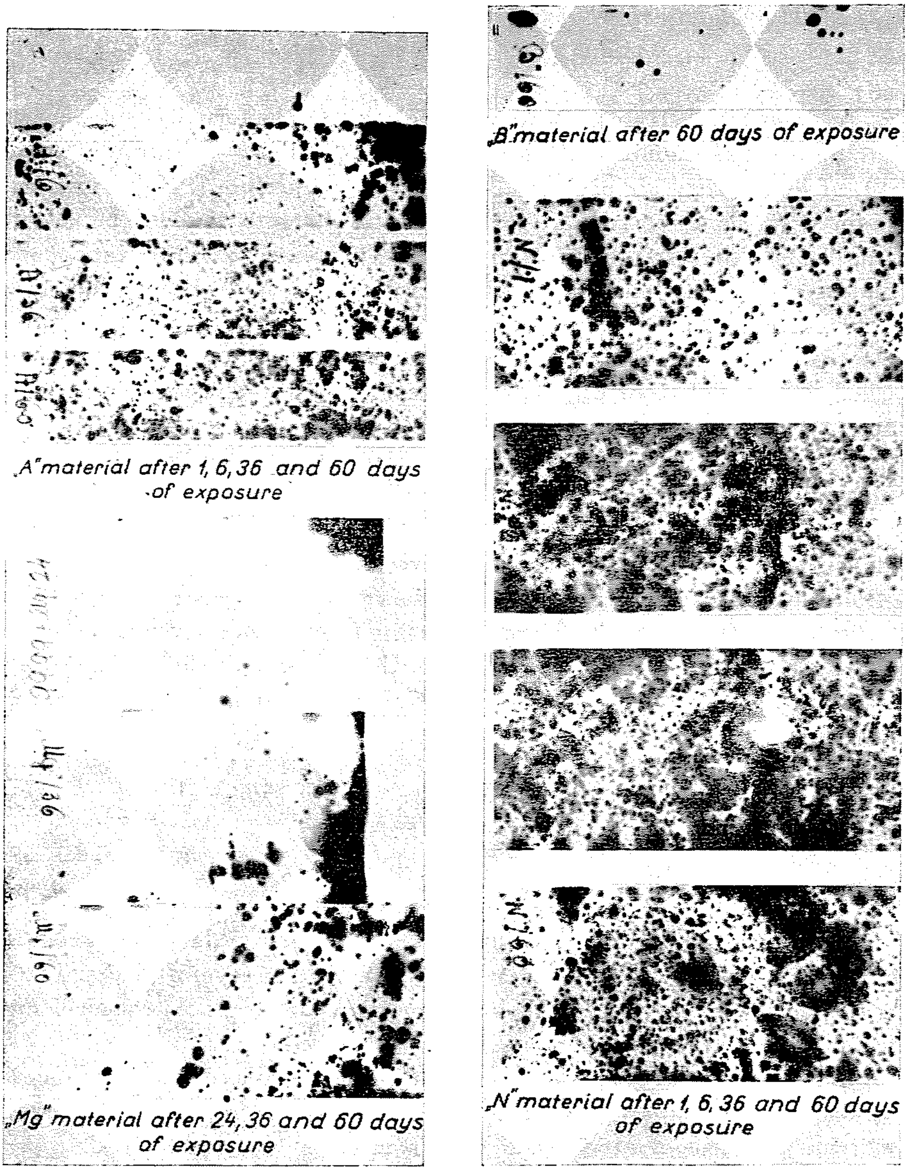

Fig. 3. Contact prints of aluminium strips previously embedded into concrete

The holes across the strips and the areas of the holes of the high-purity aluminium strips were increasing fast in course of time up to the 24th day, then the rate of corrosion slowed down. Fig. 3. There is practically no difference to be observed between the samples viewed after the 48th and 60th day. On the contrary, at the air-concrete interface strong corrosion appears in

6 days. After 36 days this interface was even more corroded and there were more holes across it. Fig. 4.

On samples marked "Mg" the cavity-like corrosion scars were widening in the course of time but perforation could only be detected on the sample investigated after 24 days. After the 36th day the desintegration of the mate-

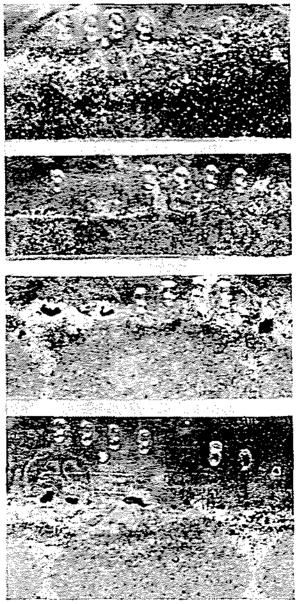

Fig. 4. The air to concrete interface of high-purity aluminium strips after 1, 6, 36 and 60 days embedded into concrete

rial started quickly and on the 60th day there was no difference between it and the sample marked "N" (Fig. 3). On the other hand, the concrete-air interface was sound. According to the experimental results the magnesium, alloyed to the high-purity aluminium increased the incubation period of the metal without changing remarkedly its corrosion resistance.

The appearance of corrosion on virgin aluminium is different from that on high-purity metal. On samples marked "A" the rate of corrosion was lower, the diameter of holes less (Fig. 3). At the same time the surface was more uneven though the air-concrete interface was sound even after 60 days of storing.

The Al—Mg—Si alloy proved to be the most resistant. In spite of the fact that the uneveness of the surface was the same as that of the virgin aluminium in the beginning, the first perforations could only be detected after storing for 60 days. The incubation-period of corrosion was much greater for samples marked "Mg" and "A", and — apart from the initial uneven surface —

the alloy Al—Mg—Si could be considered resistant against corrosion. The air-concrete interface was sound even after 60 days of storing.

The measurement of the thickness of the bands were in agreement with the findings of the investigations of the pitting, and the findings of corrosion tests on aluminium rods. In Table 6 the change of the thickness of the bands could be seen as a function of the duration of corrosion.

Table 6

Change in thickness of strips embedded into concrete cubes kept in dry atmosphere

Designation	Thickness (mm)								
	Original	after a duration of (days)							
		1	4	6	14	24	36	48	60
N	0.120	0.115	0.110	0.120	0.105	0.105	0.100	0.100	0.100
Mg	0.120	0.115	0.110	0.110	0.110	0.100	0.100	0.100	0.100
A	0.115	0.110	0.110	0.110	0.110	0.110	0.100	0.105	0.105
B	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110

It can be seen from Table 6 that the thickness of the high-purity aluminium bands was decreased by about 20% in 60 days. On the contrary, the change of thicknesses in virgin aluminium bands was of the order of 10% and for that of Al—Mg—Si alloys a decrease in thickness could not be detected, even by micrometer. It is characteristic that with concrete, following a period of rapid attack it slows down and for the sound metallic looking parts of even highly perforated samples the decrease in thickness did not exceed 0.020 mm after 60 days.

Table 7

The change in bending number of bands
(The curvature of the edges of the dies is 1 mm)

Designation	Original band	Bending number after a period of corrosion of days				
		1	6	14	48	60
N	45—50	45	35	30	28	—
Mg	35—38	38	38	38	34	26
A	33—36	35	31	31	30	28
B	30—33	33	32	30	28	29

The change of the bending number of the strips as a function of time is summarized in Table 7. The change in the bending numbers indicate that the high-purity aluminium is attacked mostly by concrete. It can be seen that the high-purity aluminium alloyed with magnesium is much damaged after 48 hours of corrosion. The bending numbers of material "B" are practically unchanged.

As a result of the experiments conducted to determine the rate of corrosion, the following can be stated.

1) On the surface of high-purity aluminium samples the corrosion due to the action of concrete resulted in the formation of scars (holes) deeper than 0.1 mm even in 24 hours. As a comparison, these corrosion scars were considerably smaller for the virgin aluminium and the rate of corrosion was also less there.

2) Alloying of Mg to high purity aluminium increases the incubation period without making it resistant to corrosion.

3) The strips of Al—Mg—Si alloy can practically be considered resistant to corrosion due to concrete.

4) The rate of corrosion slows down after 24 days for all metals except for samples marked "Mg".

5) The character of the corrosion on high-purity metal is different from that on materials prepared from virgin aluminium. For the former wide cavities are formed which are divided by deep trenches. It could be assumed that the crystal boundaries were starting points of corrosion. On the contrary, at the surface of virgin aluminium base samples, many small corrosion points can be detected, the trenches due to corrosion are less deep and the average diameter of pitting is also less.

6) The peculiar corrosive action of concrete on aluminium materials of different purity could be justified according to the authors with the same mechanism by which DRALEY [5], ALTENPOHL [6], DOMONY [7] have explained the phenomena which can be observed on the surface of aluminium due to the action of water of high pressure and high temperature. According to this, the crystal-boundaries, rich in foreign atoms or metallic compounds, exert a depolarizing effect on the aggressive OH-ions and, therefore, impedes or slows down the starting of the destruction of the metal along these boundaries.

7) The evaluation of bending numbers, measured on strip samples proved that the corrosion due to the concrete changes the mechanical characteristics only as far as the resulting surface corrosion changes them. Embrittling (hydrogen-illness) could not be detected in aluminium.

II. The rate of corrosion on aluminium materials of different purity due to the attack of mortar and gypsum

The studies were further extended to determine the rate and form of corrosion in mortar and gypsum and to compare the results with those of concrete. The investigations were made with the same aluminium strip materials as with cement, except that the period of total investigation was limited in this case to only 24 days. The blocks of mortar and gypsum were crushed after 1, 3, 6, 12 and 24 days. The mortar used was of the following composition:

20% lime (CaO),
20% cement of Lábatlan,
60% sand.

Evaluation of the experimental results

The surface of the strips of virgin aluminium (A) was badly damaged even after storing for 24 hours only and numerous holes were developed across it at several places. Numerous cavities of large and small diameters occupying vast areas were observed. Though numerous holes were observed on contact replica (Fig. 5) no holes were developed on air-mortar interface.

The surface of high-purity aluminium alloyed with magnesium (Mg) was very satisfactorily preserved. It was observed that very small cavities did exist but they were few and insignificant. There were no holes across the strip and the air-mortar interface was good.

The surface of high-purity aluminium (N) was badly damaged even after storing for 24 hours. The cavities formed were deep and were of great diameters but comparatively fewer than those formed on virgin aluminium. No holes were observed either across the strip or at the air-mortar interface.

The surface of Al—Mg—Si (B) after 24 hours in mortar had shown numerous very small cavities of shallow depths. Neither holes were formed across strip nor was air-mortar interface damaged.

On the samples of virgin aluminium the holes across the strip had been found to increase up to 24th day as could be seen on contact replicas Fig. 5. Cavities formed on the surface did neither greatly enlarge nor increase in their number after 6th day. No holes were observed on the air-mortar interface.

Inspecting the surfaces of Al—Mg (Mg) it was observed that the corrosion scars pronouncedly appeared on the 12th day and actual holes were observed on the 24th day on this alloy, a bunch of holes of very great diameter were formed on the 24th day and these holes literally congruated at the centre of the plate. It could be seen from contact replica Fig. 5 the nature of these holes.

The nature of the corrosion on high-purity aluminium (N) was evidently different from that of virgin aluminium. The holes were bigger in nature but fewer in number as was observed on contact replicas (Fig. 5). The air-mortar interface had begun to damage from the 6th day.

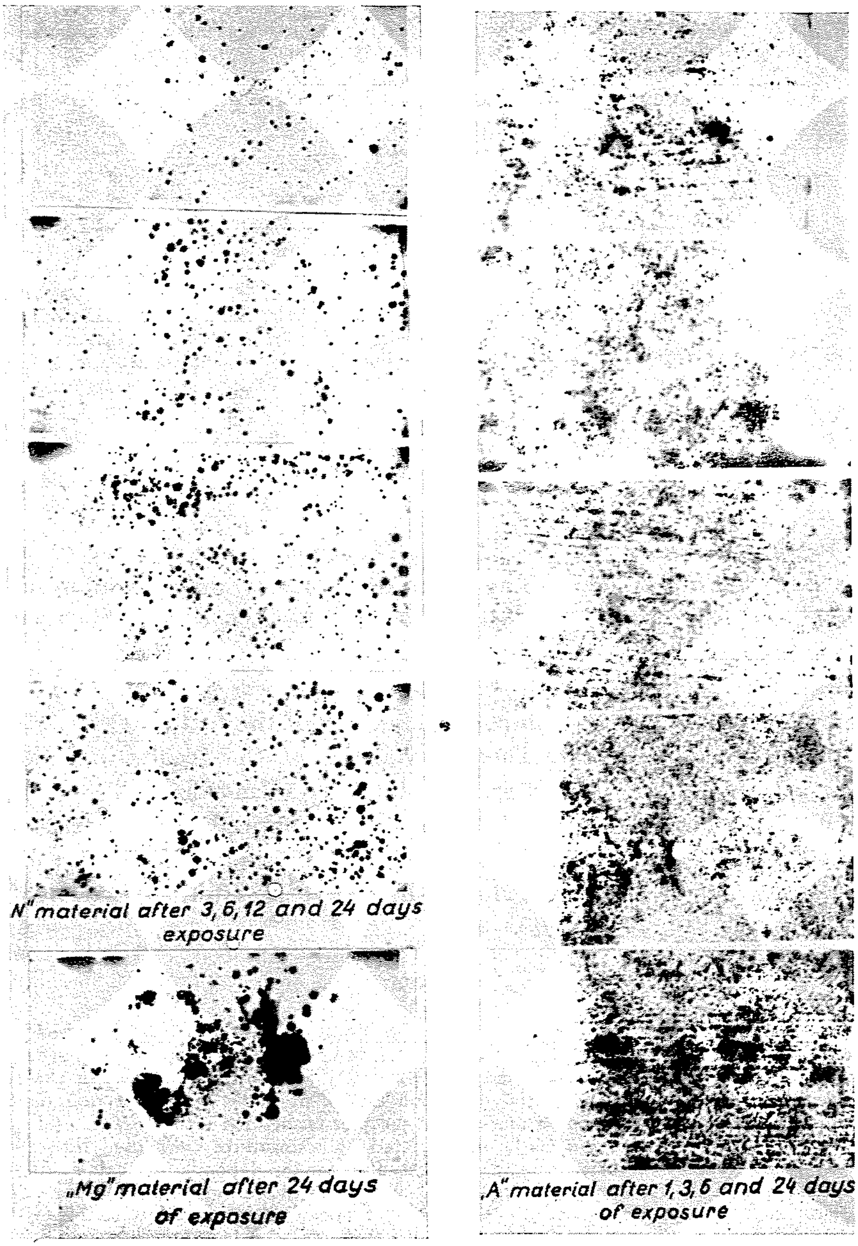

Fig. 5. Contact prints of aluminium strips held in mortar

The surface of the Al—Mg—Si (B) alloy was preserved better compared to other materials. However, within the limits of the investigation period no great damage was done to the surface. Neither holes were observed across the strip nor was air-mortar interface damaged.

The measurement of the thickness of these strips gave the following figures for 6, 12 and 24 days (Table 8).

Table 8

Material	Reduction in thickness		
	24 days %	12 days %	6 days %
Virgin aluminium (A)	20	19	18
Al-Mg (Mg)	45	15	10
High-purity aluminium (N) ...	18	15	11
Al-Mg-Si (B)	9	6	4

It was observed that Al—Mg (Mg) alloy had shown a conspicuous decrease in thickness between 12th and 24th day while virgin aluminium in spite of the high rate of initial corrosion had shown the least decrease in thickness between 12th and 24th day. The decrease in thickness was noticed to be greater in mortar than in cement. However, the corrosion was greater on virgin aluminium than on high-purity aluminium in spite of the fact that the nature of the corrosion was different. These deviations of the results with those of cement are attributable to the greater alkalinity of mortar.

With gypsum no detectable changes were noticed even after 24 days, either in surface conditions or in thickness, thereby indicating that it did not attack aluminium or aluminium alloys which were used in these investigations.

Summary

On the basis of the corrosion-tests made with different aluminium alloys embedded into concrete, mortar and gypsum the following statements could be made:

1) Our own experimental data have confirmed the findings described in the related literature [2, 3, 4], that after an initial corrosion attack of about 0.02—0.1 mm depth, no more corrosion could be observed on aluminium samples embedded into concrete and mortar. Practically no signs of corrosion could be detected on aluminium embedded into gypsum.

2) The degree of corrosion due to concrete and mortar depends on their composition. In accordance with the findings of GORO ITO [8] the virgin aluminium base Al—Mg—Si alloy was found to be the most resistant to corrosion. The corrosion resistance of high-purity aluminium was much less, even less than that of virgin aluminium embedded into concrete. Alloying with Mg did not increase the corrosion resistance of high-purity aluminium, only the incubation period was then prolonged. The corrosion resistance of high-strength virgin aluminium base alloys against concrete was higher than that of the virgin aluminium but was less than that of the Al—Mg—Si alloys.

3) The artificial strengthening of the surface oxide films did not increase the corrosion resistance of aluminium materials against concrete.

4) The degree of corrosion was but slightly affected by the moisture content of the concrete. The initial corrosion of aluminium embedded in concrete and stored in a humid atmosphere was increased only by about 15—20%.

5) The effect of the alkalinity of the building materials referred to above was more marked; however, it did not change considerably the order of the resistance to corrosion of different aluminium materials.

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G. J. V. RAJU } Fémipari Kutató Intézet Budapest XI. Fehérvári út 144.
A. DOMONY } Hungary