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Arresting Corrosion in Concrete Walls Using Thermal Insulation

Arrêt de la corrosion dans les murs en béton par une isolation thermique

Korrosionshemmung in Betonwänden durch Wärmedämmung

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SUMMARY

Exterior walls of concrete buildings frequently exhibit surface deterioration due to corroding reinforcement. Laboratory and field experiments show that it is possible to arrest the rebar corrosion in exterior walls of concrete buildings in Central European or similar climates by additional thermal insulation. This method makes it possible to arrest the rebar corrosion without the usual concrete repair and at the same time to save heating energy.

RÉSUMÉ

Les murs extérieurs des bâtiments, réalisés en béton armé, sont souvent détériorés en surface par la corrosion de l'armature. Il résulte d'expériences en laboratoire et in situ qu'il est possible d'arrêter la corrosion par une isolation thermique, dans des conditions de climat d'Europe centrale ou similaires. Cette méthode rend possible l'arrêt de la corrosion sans réparation conventionnelle du béton, tout en réduisant la consommation énergétique pour le chauffage.

ZUSAMMENFASSUNG

Aussenwände von Betonbauten zeigen häufig Oberflächenschäden infolge korrodierender Bewehrung. Labor- und Felduntersuchungen ergaben, dass es möglich ist, in mitteleuropäischem oder vergleichbarem Klima durch zusätzliche Wärmedämmung die Bewehrungskorrosion in solchen Aussenwänden zu stoppen. Diese Methode ermöglicht eine Korrosionshemmung ohne konventionelle Betoninstandsetzung bei gleichzeitiger Einsparung von Heizenergie.

1. INTRODUCTION

Exterior walls made of reinforced concrete frequently show surface deterioration due to rebar corrosion. Hand-applied concrete repair of these walls requires numerous repair steps (fig. 1 left). This repair method is expensive and the results may be imperfect.

It can be demonstrated by diffusion calculations that it is possible to dry the exterior walls of concrete buildings in Central European or similar climates by attaching an additional thermal insulation to the outside of these walls. Preliminary results were reported at the IABSE symposium in Lisbon, 1989 [1]. By the undermentioned tests it will be verified that it is possible to arrest rebar corrosion by means of additional thermal insulation (fig. 1 right).

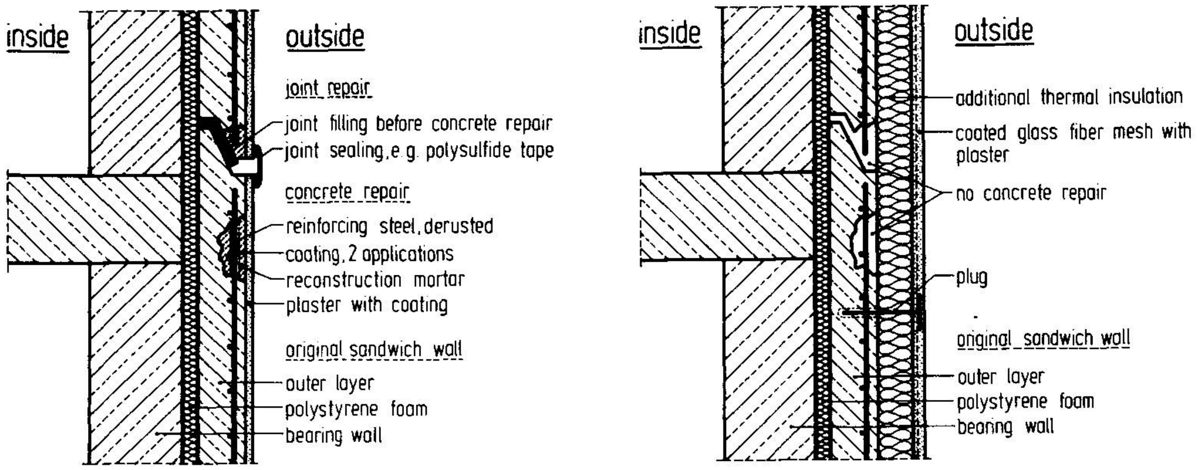

Fig. 1 Common method of concrete repair to the exterior of a sandwich wall (left), alternative repair using an external thermal insulation composite system (ETICS, right)

2. THEORY OF ARRESTING CORROSION BY THERMAL INSULATION

Steel corrosion in reinforced concrete requires that the following physical conditions occur at the same time [1, 2], if one of these conditions is missing, there will be no corrosion:

- the presence of oxygene is necessary - the concrete porosity makes the penetration of oxygene inevitable,
- the passivation of the rebar surface must be neutralized by chlorides or carbonation (the penetration of chlorides is a problem only for de-icing salt contaminated bridges and marine structures, carbonation of concrete is a slow but inavoidable process) - when deteriorations are visible the rebar surface is evidently depassivated,
- the concrete moisture must enable an electrolyte.

Thus, the only possibility of arresting rebar corrosion is to lower the concrete moisture level in a way, that there is no sufficient electrolyte. Experience with existing dwelling and office buildings in Central European climate shows that the concrete walls inside the buildings are considerably carbonated, but the rebars do not corrode there. It can be concluded that there is no electrolyte present in the dry but carbonated concrete.

Diffusion calculations demonstrate that an additional thermal insulation to the outside of a concrete sandwich exterior wall (cp. fig. 1 right) only slightly reduces the moisture of the bearing wall but significantly reduces the moisture in the outer layer of the wall. Thus, rebar corrosion may be arrested in concrete exterior walls in Central European climate by the application of thermal insulation.

3. EXPERIMENTS

3.1 Laboratory Tests

In a first step, reinforcing steel specimens were stored in industrial atmospheres of different relative humidities. Later, the mass loss (material consumption) by corrosion was investigated. The tests showed that for a relative humidity up to 50 % no corrosion occured, and that 60 % r.h. or more caused growing steel corrosion depending on the reinforcing steel type used [1, 2].

In a second step, accelerated carbonated concrete specimens with steel bars were stored in different relative humidities. Later the specimens were investigated for steel corrosion (fig. 2):

- all steel bars showed a basic corrosion caused by the carbonation of the concrete specimens,
- after four years of investigation the basic corrosion level did not change in specimens which were stored in climates with a relative humidity of 60 or 70 %, for specimens stored in a climate of 80 % r.h. the rebar corrosion increased negligibly,
- when stored in 90 % relative humidity the rebar corrosion in the specimens showed a significant growth over the time.

These experiments show that steel corrosion in reinforced concrete can be arrested if the concrete moisture level is in equilibrium to not more than 80 % relative humidity to the surrounding atmosphere, a result which does not depend on the reinforcing steel type.

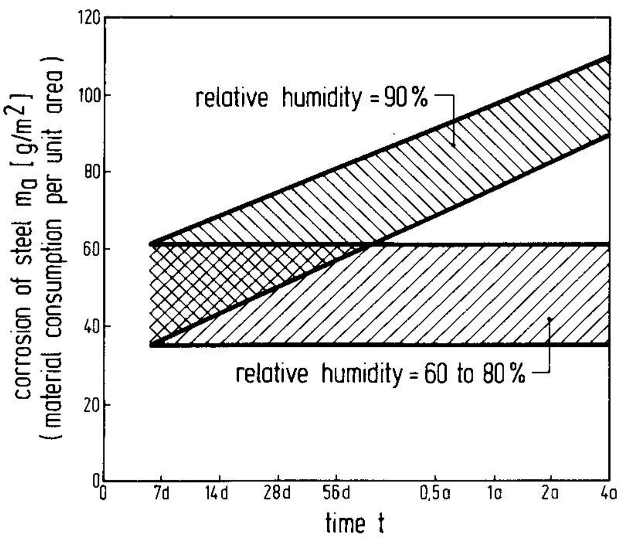

Fig. 2 Mass losses of rebars in carbonated concrete specimens stored at different r.h.

Type	Additional thermal insulation	Weather protection
1	None (zero test)	No additional
2	6 cm polystyrene foam	Polymer resin plaster
3	6 cm mineral wool	Lime plaster
4	6 cm fiberglass	Curtain wall

Table 1 Investigated types of additional thermal insulation systems

3.2 Long-Term Field Tests

To verify the above mentioned theory, long-term field tests were made on a residential building in Berlin. Two external thermal insulation composite systems (ETICS) and a curtain wall were attached to the building in September 1987 (table 1) [1, 2].

Temperatures and moistures in the concrete sandwich exterior walls, with and without the additional thermal insulation systems, were recorded for more than five years. The combined transducers for temperature and relative humidity (for measuring the equilibrium humidity) were installed as follows:

- rain and sun protected in the atmosphere,
- in the bearing walls and the outer layers of the investigated sandwich walls,
- in the used apartments behind the investigated walls [2].

The measurements were recorded automatically using a print recorder as well as a personal computer. The measured equilibrium humidities were compared with computer calculations carried out by a time-dependent water-vapor diffusion calculation program [3]:

- the outer layers of the sandwich walls were drying behind the additional thermal insulation significantly, and after a few years the concrete moisture level was in an equilibrium at the measured relative humidity of 40 to 70 % (fig. 3),
- the bearing walls were drying, too, and after a few years the concrete moisture level was in an equilibrium at the measured relative humidity of 30 to 60 %.

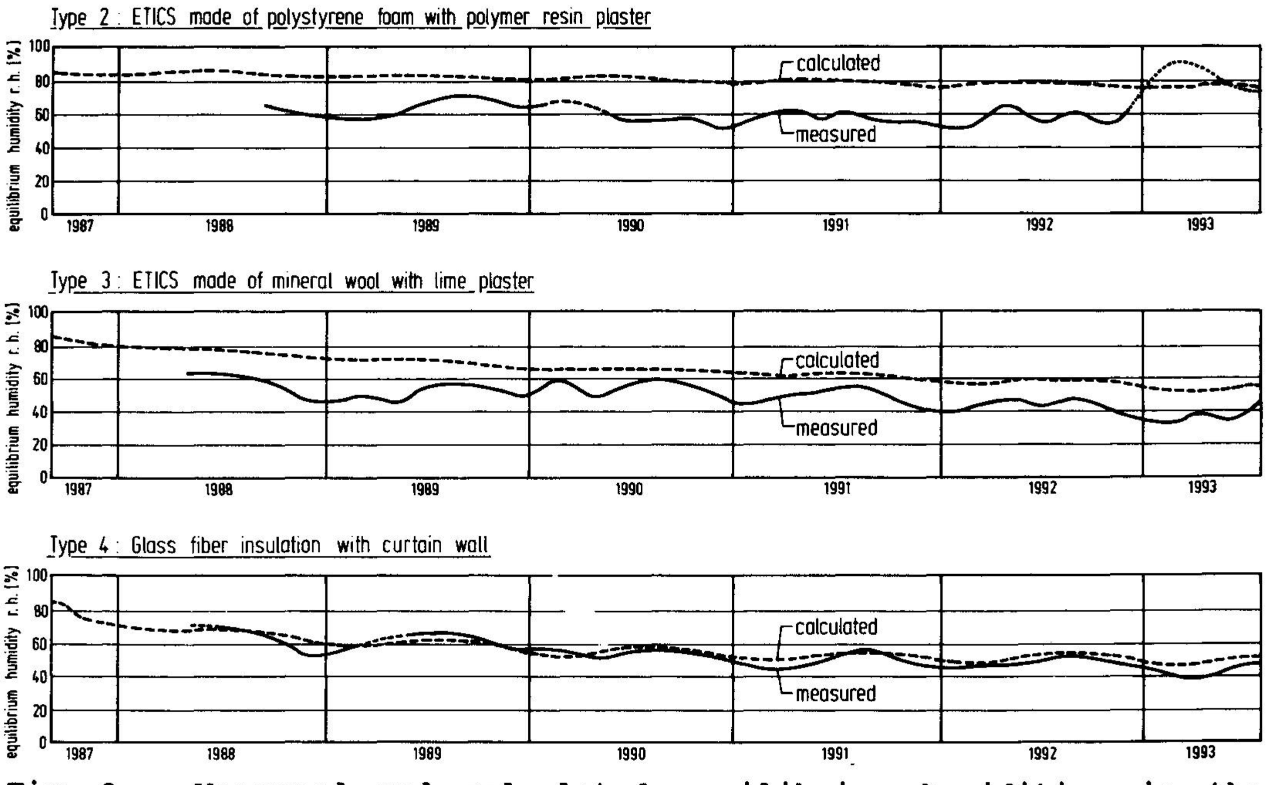

Fig. 3 Measured and calculated equilibrium humidities in the outer layers of concrete sandwich exterior walls with additional thermal insulation

The moisture levels measured in the additionally insulated sandwich walls were dependent on the type of thermal insulation and on the rain protection: Behind an ETICS made of polystyrene foam with polymer resin plaster the concrete wall was drying slowly, behind an ETICS made of mineral wool insulation with lime plaster it was drying more quickly; and behind a curtain wall with fiberglass insulation the sandwich wall was drying most quickly [2].

3.3 Practical In-Situ Tests

To investigate the reliability of the above mentioned method in practice three series of field tests were made:

- steel bars were placed in the airspace between the curtain wall and the additional fiberglass insulation (type 4, cp. table 1),
- steel bars were mounted between the different additional thermal insulations (type 2, 3 and 4, cp. table 1) and the outer layer of the original sandwich wall, too.

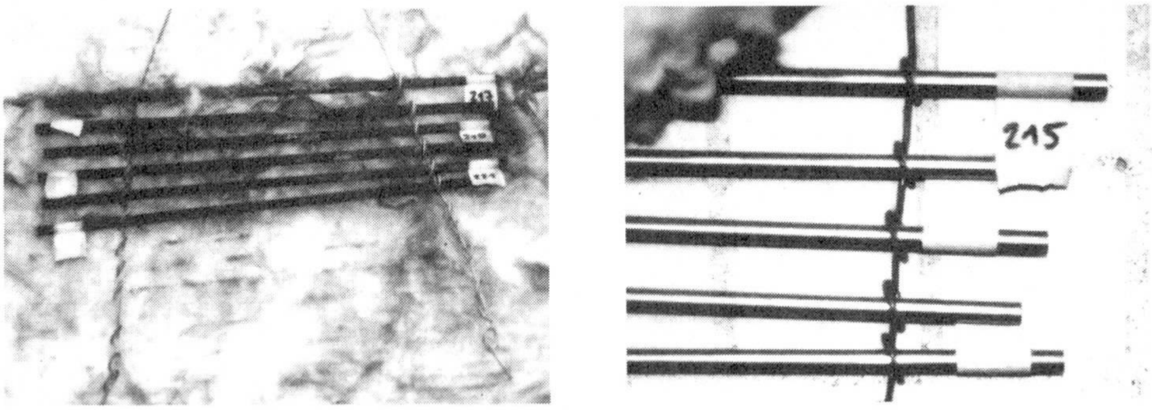

Fig. 4 Unprotected steel bars after one year of in-situ storage between a curtain wall and the fiberglass insulation behind it (left) and between the fiberglass insulation and the outer layer of the sandwich exterior wall (right)

During one year, the thermal insulation systems were opened every three months and the steel bars were examined:

- the bars which were only rain protected, i.e. in the airspace just behind the curtain wall (type 4), were clearly corroded (fig. 4 left), while the rebars mounted between the fiberglass insulation and the sandwich wall were free of any corrosion (fig. 4 right),
- the rebars mounted between the mineral wool insulation (type 3) and the sandwich wall were almost free of corrosion,
- the rebars mounted between the diffusion delaying polystyrene foam insulation (type 2) and the sandwich wall were partially corroded.

After the visual observation the mass loss (material consumption) of all steel bars was investigated. It was obvious that the thermal insulation systems of type 3 and type 4 were suitable to assess the rebar corrosion in concrete exterior walls. Type 2 seemes to be not sufficient, but in this practical test the steel bars showed corrosion in atmospheric conditions and not in realistically carbonated concrete (cp. fig. 2).

4. CONCLUSIONS

Field and laboratory tests showed that it is possible to arrest rebar corrosion in concrete walls in Central European or similar climates by the application of thermal insulation. Additional corrosion protection (as applied in common concrete repair) seems to be not necessary because

- the concrete layers of sandwich exterior walls with additional thermal insulation will get moistures in equilibrium to relative humidities of 30 to 70 % after a few years of drying,
- steel in carbonated concrete specimens needs more than 80 % relative humidity for corrosion (fig. 5).

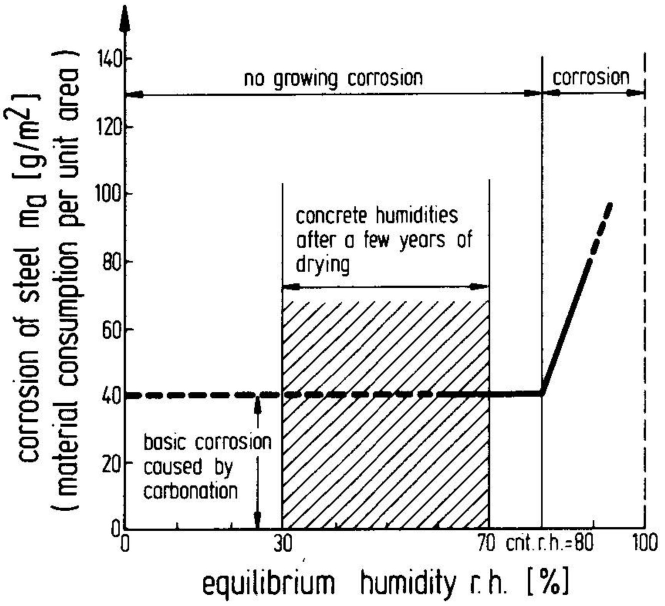

Fig. 5 Scheme of arresting rebar corrosion in concrete exterior walls using additional thermal insulation

Thus, the growth of corrosion of the reinforcement in concrete exterior walls with additional thermal insulation will be impossible. Practical in-situ tests have confirmed the advantages of this method if suitable thermal insulation systems are attached to the exterior walls. It can in fact be established that rebar corrosion in these exterior walls will be arrested, so that a state-of-the-art concrete repair of such walls - which is expensive and may be imperfect - is rendered unnecessary.

Compared with the expense of a hand-applied concrete repair, the costs of additional thermal insulation are quite low. Thus, the rehabilitation of concrete buildings using thermal insulation instead of the common concrete repair will profit, too [4].

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