# REZISTENȚA BETONULUI CU CONȚINUT DE DEŞEURI DE CAUCIUC LA PENETRAREA IONILOR DE CLOR
# RESISTANCE TO CHLORIDE ION PENETRATION OF CONCRETE CONTAINING SCRAP RUBBER POWDER

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***The previous studies show that the concretes containing scrap rubber powder with particle size of 180um, 150um and 120um exhibit a excellent freezing resistance durability. The influence of rubber powder content, particle size and water-cement ratio on resistance to chloride ion penetration of concrete were studied. The experimental results illustrate that the resistance to chloride ion penetration of rubber concrete improved along with the increasing of rubber powder content, decreased with powder particle size and decreased with the water-cement ratio. Compared with the reference concrete, the permeability grade of concrete with rubber powder content of over 20kg/m$^3$ and powder particle size of less than 150$\mu$m will change from "low" grade to "medium" grade.***

***Studiile anterioare arată că betoanele care conțin pulbere de deşeu de cauciuc, cu mărimea particulelor de 180µm, 150µm 120µm, prezintă o rezistență la îngheț-dezgheț excelentă. A fost studiată influența conținutului de pulbere de cauciuc, a dimensiunii particulelor şi a raportului apă-ciment asupra rezistenței betonului la penetrarea ionului de clorură. Rezultatele experimentale ilustrează faptul că rezistența betonului la penetrarea ionului de clorură este favorabil influnțată de creşterea conținutului de pulbere de cauciuc, de micşorarea dimensiunii particulelor de pulbere şi reducerea raportului apă-ciment. Prin comparație cu betonul de referință, gradul de permeabilitate al betonului cu un conținut de peste 20kg/m$^3$ praf de cauciuc cu dimensiunea maximă a particulelor de 150$\mu$m s-a modificat de la "scăzut" la "mediu" .***

***Keywords:*** *scrap rubber powder, concrete, chloride ion penetration, durability*

## 1. Introduction

With the rapid development of automobile industry, the scrap tire as one of new pollution sources is gradually becoming the environmental burden, and the recycling of scrap tire has drawn wide attention in the world. To make rubber concrete by the addition of crushed scrap tires not only solves the recycling problem of scrap tire, but also develops one kind of new-type green building material. The rubber concrete has such advantages as shock absorption, noise reduction, thermal insulation, toughness, ductibility, crack resistance and durability, and thus becomes the research focus in the fields of concrete [1-5].

The concrete used for road and bridge surface in cold area is often eroded by chloride ions after ice-removing salt treatment. Furthermore, the concrete exposed to seawater will be eroded by chloride ions to some degree. The chloride ion penetrates the concrete to cause exfoliation corrosion, which even extends to surface of reinforcing bar, damages the alkaline passivation film and eventually causes the electrochemical reaction and rust of reinforcing bar.

The previous research has shown that [6-7] compared with ordinary concrete(with normal aggregate, without rubber powder), the resistance to chloride ion penetration of concrete with rubber powder will be obviously strengthened; this is of important practical significance for solving the above problem better.

Through former researches, the author found that the rubber concrete containing scrap rubber powder with particle size of 180$\mu$m, 150$\mu$m and 120$\mu$m has excellent freezing resistance durability[8-9]. This paper researches the resistance to chloride ion penetration of concrete after addition of scrap rubber powder with particle size of 180$\mu$m, 150$\mu$m and 120$\mu$m, and respectively analyzes the influence of rubber powder content, particle size and water-cement ratio on the resistance to chloride ion penetration of concrete.

## 2. Raw materials and mix proportion design

### *2.1 Raw materials*

(1) Cement: Portland Ordinary 42.5R (China Standard GB175-2007), made by Dalian Onoda Cement Co., Ltd., the phsical parameters and properties of cement are shown in Table 1 and

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**Table 1**

Cement component and physical parameters /*Caracteristici chimice şi fizice ale cimentului*

| Chemical composition (%) | | LOI (%) | Specific surface area ($m^2$/g) | Setting time (min) | | Soundness |
|---|---|---|---|---|---|---|
| MgO | $SO_3$ | 2.07 | 373 | Initial setting | Final setting | Boiling |
| 4.78 | 2.26 | | | 180 | 245 | Qualified |

**Table 2**

Properties of cement/ *Rezistenţele mecanice ale cimentului*

| Compressive strength / *Rezistenţa la compresiune* (MPa) | | Bending strength / *Rezistenţa la încovoiere* (MPa) | |
|---|---|---|---|
| 3 days /*zile* | 28 days/*zile* | 3 days/*zile* | 28 days/*zile* |
| 27.5 | 51.5 | 5.6 | 8.6 |

Table 2 according to China Standard for general purpose portland cement (GB175-2007).

(2) Fine aggregate: river sand, with fineness modulus of 2.83, with apparent density of 2.72g/$cm^3$, bulk density of 1524kg/$m^3$.

(3) Coarse aggregate: evenly graded with particle size of 5-25mm, apparent density of 2.73g/cm3, bulk density of 1556kg/$m^3$, flakiness index of 4%, crushing index of 2.75%.

(4) Water for mixing: tap water.

(5) Water-reducing agent: SW-4 superplasticizer produced by Dalian Sunway Building Materials Co., Ltd., China, with water reducing rate of 20%.

(6) Rubber powder: 180μm, 150μm and 120μm scrap tire rubber powder, Obtained from Sichuan Luyuan Science & Technology Co., Ltd., China, with density of 1.116g/$cm^3$. The average particle size and bulk density of rubber powder are shown in Table 3.

**Table 3**

Physical properties of rubber powder
*Caracteristicile fizice ale pulberii de cauciuc*

| Average particle size (μm) | 180 | 150 | 120 |
|---|---|---|---|
| Bulk density (kg/$m^3$) | 301 | 292 | 284 |

### 2.2. *Mix ratio design*

In order to make concrete with the same slump (120mm), certain amount of water-reducing agent was added to concrete with different rubber powder contents. The following 7 mix ratios were designed for the purpose of researching the resistance to chloride ion penetration of concrete (with different rubber powder contents, particle sizes and water-cement ratios). The test on resistance to chloride ion penetration adopted φ100mm×50mm cylindrical sample, which had been cured for 28 days before test. The mix proportion ratio is shown in Table 4. The samples for compression strength were side length of 150mm cubic specimens according to China Standard for test method of mechanical properties on ordinary concrete(GB50010-2010). The workability of fresh concrete mesured with a slump meter (300mm height) according to China standard for test methods of long-term performance and durability of ordinary concrete (GB/T 50082-2009).

**Table 4**

Mix ratio / *Compoziţia betonului*

| No. | Water-cement ratio *Raportul apă/ciment* (%) | Water *Apă* (Kg) | Cement *Ciment* (Kg) | Sand *Nisip* (Kg) | Gravel *Pietriş* (Kg) | Plasticizer *Plastifiant* (%) | Rubber powder *Pulbere de cauciuc* (Kg) | 28d strength /$fc_{28}$ (MPa) |
|---|---|---|---|---|---|---|---|---|
| CC-L | 0.42 | 190 | 452 | 678 | 1060 | 0.8 | 0 (150 um) | 48.3 |
| RC-L-1 | 0.42 | 190 | 452 | 678 | 1060 | 0.8 | 10 (150 um) | 43.5 |
| RC-L-2 | 0.42 | 190 | 452 | 678 | 1060 | 0.8 | 20 (150 um) | 40.2 |
| RC-L-3 | 0.42 | 190 | 452 | 678 | 1060 | 0.8 | 30 (150 um) | 41.6 |
| RC-L-4 | 0.42 | 190 | 452 | 678 | 1060 | 0.8 | 20 (180 um) | 42.4 |
| RC-L-5 | 0.42 | 190 | 452 | 678 | 1060 | 0.8 | 20 (120 um) | 39.7 |
| RC-L-6 | 0.66 | 190 | 288 | 774 | 1068 | 0.5 | 20 (150 um) | 16.8 |
| RC-L-7 | 0.54 | 190 | 352 | 733 | 1055 | 0.6 | 20 (150 um) | 33.2 |

**Note**: the code in the table is arranged according to RC-L-n; CC-reference concrete, RC-rubber concrete, n-No. / *Codul este stabilit RC-L-n, conform cu betonul de referinţă -CC, betonul cu pulbere de cauciu – RC, Nr-n*

## 3. Test on resistance to chloride ion penetration

### *3.1. Test method and evaluation index*

The test method conformed to ASTM C1202 method[10], namely standard test method for electrical indication of concrete's ability to resist chloride ion penetration. The basic principles are: under the influence of DC voltage, the chloride ions can move to positive pole via concrete sample, and the measurement of electric quantity flowing through concrete can reflect the quantity of chloride ions penetrating concrete. According to the test results, the resistance of concrete to chloride ion penetration is classified into different grades, with classification standard and basis shown in Table 5.

rubber powder may enable the electric flux to decrease to $1519^0$C from original $2868^0$C,which means, the chloride ion permeability grade of concrete changes from original medium grade to low grade. This variation trend may attribute to the "bubble effect" of rubber powder, the rubber powder act as close bubbles in the concrete, which block the transportation of chloride ion.

### ***3.2.1 Influence of water-cement ratio on resistance to chloride ion penetration of rubber concrete***

It can be seen obviously from Table 6 and Figure 1 that, for the rubber concrete with the same rubber powder content (20%) and power particle size (150μm), the electric flux of concrete will decrease along with the decrease in water-cement ratio, that is, the resistance to chloride ion

**Table 5**

ASTM C1202 evaluation of concrete resistance to chloride ion penetration
*Parametrii ASTM C1202 de evaluare a rezistenței betonului la penetrarea ionilor clorură*

| Electric flux<br>*Flux de curent*<br>(C) | Chloride ion penetration<br>*Penetrarea clorură* | Electric flux<br>*Flux de curent*<br>(C) | Chloride ion penetration<br>*Penetrarea clorură* |
|---|---|---|---|
| >4000 | High /*Mare* | 100~1000 | Very low/*Foarte mică* |
| 2000~4000 | Medium /*Medie* | <100 | Negligible/ *Neglijabilă* |
| 1000~2000 | Low/*Mică* | --- | --- |

### 3.2 Test results and analysis

**Table 6**

Chloride ion penetration test results
*Rezultatele penetrării ionului clorură*

| Code<br>*Cod* | CC-L | RC-L-1 | RC-L-2 | RC-L-3 |
|---|---|---|---|---|
| Electric flux<br>*Flux de curent*<br>(C) | 2868 | 2070 | 1650 | 1523 |
| Code<br>Cod | RC-L-4 | RC-L-5 | RC-L-6 | RC-L-7 |
| Electric flux<br>*Flux de curent*<br>(C) | 2142 | 1519 | 4983 | 2566 |

The test results reveal that for the concrete with the same designed strength, the addition of

penetration of concrete will be better. In this test, compared with the rubber concrete with water-cement ratio of 0.66, the electric flux of rubber concrete with water-cement ratio of 0.54 and 0.42 is decreased by 48.5% and 66.9% respectively. This result may atrributed to the lower porosity of concrete with lower water-cement ratio.

### ***3.2.2. Influence of rubber powder content on resistance to chloride ion penetration of concrete***

As shown from Table 6 and Figure 2, for the rubber concrete with the same water-cement ratio (W/C=0.42) and power particle size (150μm), the resistance to chloride ion penetration of concrete will be strengthened along with the increase in rubber

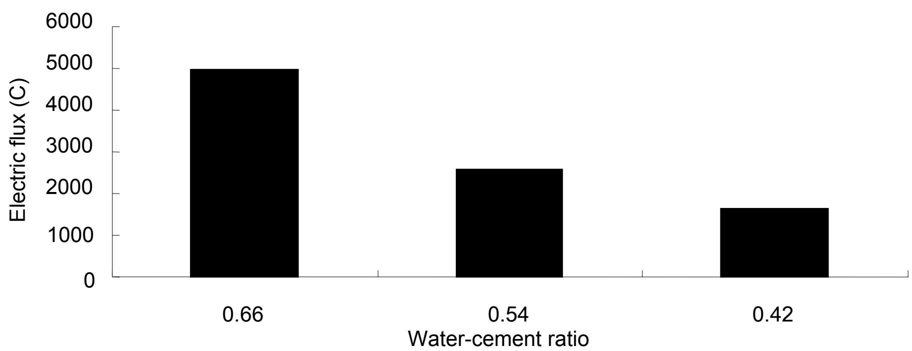


Fig. 1 - Electric flux vs. Water-cement ratio / *Influența raportului apă/ciment asupra fluxului de curent electric.*

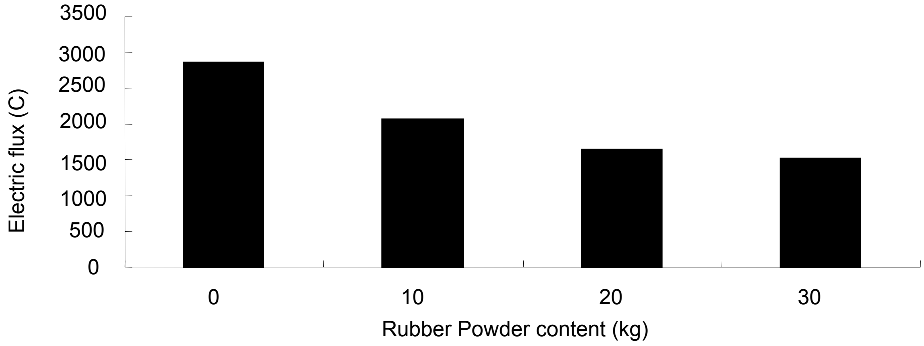


Fig. 2 - Electric flux vs. Powder content / *Influența conținutului de pulbere de cauciuc asupra fluxului de curent electric*

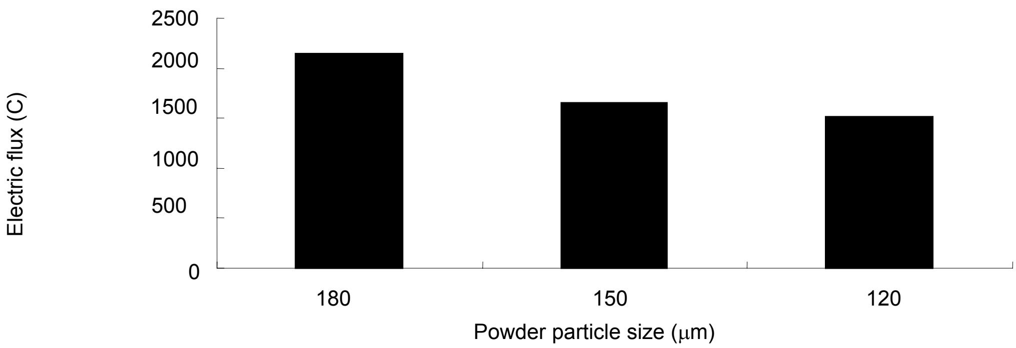


Fig. 3 - Electric flux vs. Powder particle size / *Influența dimensiunii maxime a particulei pulberii de cauciuc asupra fluxului de curent electric.*

powder content. Compared with the reference concrete without rubber powder, the electric flux of concrete with rubber powder will be decreased by 27.8%, 42.5% and 46.9% respectively when the rubber powder content is respectively 10kg/m$^3$, 20kg/m$^3$ and 30kg/m$^3$. For the concrete with 150μm rubber powder, if the rubber powder content is over 20kg/m$^3$, the electric flux will fall below 2000$^0$C, that is, the permeability grade of concrete becomes "low" grade.

### *3.2.3. Influence of rubber powder particle size on resistance to chloride ion penetration of concrete*

It can be seen from Table 6 and Figure 3, for the rubber concrete with the same water-cement ratio (W/C=0.42) and rubber powder content (20%), the electric flux of concrete will decrease along with the decrease in powder particle size, and the resistance to chloride ion penetration of concrete will be better. Compared with the concrete with 180μm rubber powder, the electric flux of concrete with 150μm rubber powder and the electric flux of concrete with 120 μm rubber powder are respectively decreased by 23% and 29%. After the addition of 20kg/m$^3$ rubber powder, the electric flux of concrete with 150μm rubber powder and the electric flux of concrete with 120μm rubber powder are respectively 1650$^0$C and 1519$^0$C, with permeability grade of concrete decreasing to "low" grade both[11]. This phenomenon may because of incorporating finer rubber powder, the "bubble effect" will be more obvious.

## 4. Conclusion

It can be seen from above test results that the addition of rubber powder will influence the resistance to chloride ion penetration of concrete to some degree; the detailed influence conditions: the resistance to chloride ion penetration of rubber concrete is strengthened along with the decrease in water-cement ratio, increase in rubber powder content and decrease in powder particle size. Compared with the concrete of common strength, the permeability grade of concrete with rubber powder content of over 20kg/m$^3$ and powder particle size of less than 150μm will become "low" grade from "medium" grade. The reson thereof may be that the rubber powder act as some closed bubbles in the concrete, and block the transportation of water and other ions.

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