Influence of lithium slag from lepidolite on the durability of concrete

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Abstract. This paper mainly studies the effect of lithium slag from lepidolite on the property of concrete including dry shrinkage, anti-carbonation, wear resistance and chloride ion resistance. Concrete interface structure has been observed with SEM. The results show that adding lithium slag to concrete can improve concrete property including dry shrinkage, wear resistance and chloride ion resistance. However, the wear resistance tends to decrease when the amount of lithium slag reach 20%. Lithium slag also has negative effect on anti-carbonation property. With the increasing amount of lithium slag, anti-carbonation property of concrete decrease gradually.

1. Introduction

Using lithium slag as concrete admixture can solve the pollution problem caused by excessive lithium slag in industrial production. Domestic experts have done a lot of researches on adding lithium slag to concrete. Zhang Lanfang, Chen Jianxiong and some other researchers[1~4] studied the effect of admixtures including lithium slag, fly ash, mineral powder on concrete property including working performance, strength, anti-carbonation, frost resistance. Zhao Ruopeng[5] produced high fluidity concrete compound lithium slag and silicon powder which strength can reach 100MPa. Wen Yong and Liu Guojun[6] studied the effect of lithium slag on fresh properties and surface area of concrete. WangGuoqiang[7] also studied the effect of lithium slag on strength and crack resistance. However, there is little researches on the application of lithium slag from Yichun lepidolite (lithium slag for short) on concrete, also no systematic researches on endurance of concrete adding lithium slag. Systematic researches about the effect of lithium slag on concrete property including dry shrinkage, anti-carbonation, wear resistance, chloride ion resistance and surface structure can be the theory reference in actual application.

2. Experiment

2.1. Raw material

Cement: P.O42.5R cement produced by East Asia JiangXi Cement Co. Ltd. The apparent density of the cement is 3.1g/cm³. Lithium slag: Lithium slag extract from lepidolite produced by Jiangxi Ganfeng Lithium Co. Ltd. The specific surface of lithium slag is equal to 550m²/kg and the middle diameter of it equal to 12μm. The chemical constituents of lithium slag are given in Table 1. Fine aggregate: Sand in gan river with fineness modulus of 2.4 and apparent density of 2.6g/cm³. Coarse
aggregate: Continuous grading limestone artificial gravels with the maximum grain size of 20mm. Water reducing agent: Polycarboxylate superplasticizer (powder) saled in the market with water reducing ratio of 26%.

| Raw material | SiO₂ | Al₂O₃ | CaO | Fe₂O₃ | MgO | SO₃ | Na₂O | K₂O | TiO₂ | Loss | Sum |
|--------------|------|-------|-----|-------|-----|-----|------|-----|------|------|-----|
| Lithium slag | 47.62| 21.56 | 2.02| 0.48  | 0.12| 0.03| 10.68| 3.05| 3.46 | 0.14 | 90.63|

2.2. Testing method
The testing of drying shrinkage, anti-carbonization and chloride penetration resistance of concrete refer to GB/T 50082-2009 Standard for test methods of long-term performance and durability of ordinary concrete. The wear resistance of concrete is tested in accordance with the JTG E30-2005 highway engineering and cement concrete testing rule. Meso-structure: Using QUANTA 200FEG Field Emission Environment Scanning Electron Microscope (FEI, America) analysis interface meso-structure of cement concrete. The mix proportion of cement concrete shows in Tab.2, water-binder ratio is 0.47 and the mixing value of the water reducer is 0.4% invariably.

| Sample | Water | Cement | Lithium slag | Fine aggregate | Coarse aggregate |
|--------|-------|--------|--------------|----------------|-----------------|
| L0     | 234   | 500    | 0            | 640            | 1139            |
| L1     | 234   | 450    | 50           | 640            | 1139            |
| L2     | 234   | 400    | 100          | 640            | 1139            |
| L3     | 234   | 350    | 150          | 640            | 1139            |

3. Results and discussion

3.1. The effects of lithium slag on concrete drying shrinkage
Drying shrinkage is referred to the irreversible shrinkage caused by the loss of adsorbed water in gel pores and capillary pores in unsaturated air after the concrete maintenance stopped. The drying shrinkage after curing may cause cracks in concrete without loading. To research the effects of lithium slag on concrete drying shrinkage, we designed two variables, the mount of lithium slag and concrete ages. The test results are shown in Fig.1. As depicted in Fig.1, the dry contraction percentage was steady and the increasing speed of it was slow after 60d. With the increment of the mixing mount of lithium slag, the dry contraction percentage was decreased. Comparing to the specimen without lithium slag (L0), the dry contraction of the specimen with 30% lithium slag decreased 23% on 180d. It may because Lithium slag need plenty of water causing that. Compared with L0, there is less adsorbed water in gel pores and capillary pores in lithium slag concrete, making the dry contraction percentage of concrete decreases.

![Fig 1. The effects of lithium slag on concrete drying shrinkage](image-url)
3.2. The effects of lithium slag on concrete carbonation resistance
Carbonation resistance is related to the concrete durability closely. It is used to evaluating the service life of reinforced concrete structures\(^{[6]}\). To study the effects of lithium slag on concrete carbonation resistance, we tested carbonation depth in different ratios of lithium slag and different concrete ages. The test results are shown in Fig.2. As depicted in Fig.2, with more lithium slag and high of concrete ages, the carbonation depth grows. The carbonation average depth of concrete without lithium slag L0 is 3mm on 28d. However, the carbonation average depth of concrete with 30% lithium slag L3 is 11mm. It may because that lithium slag can replace the cement and have secondary hydration with the production of cement hydration. So the alkalinity of concrete decreased. The neutralization resistance decreases in the process of CO\(_2\) infiltration which causes that the carbonation resistance of concrete decreases gradually with the increasing of lithium slag.

![Fig 2. The effects of lithium slag to concrete carbonation resistance](image)

3.3. The effects of lithium slag on concrete chloride-penetration resistance.
When chloride ion infiltrate and form the galvanic cell in concrete, passive film on the surface of reinforcement will be destroyed easier and the reinforcement will rust faster. Fig.3 shows that there is a positive correlation between the amount of adding lithium slag and chloride-penetration resistance. Electric flux of concrete L3 adding 30% lithium slag decrease about 43% compared to concrete L0 without adding lithium slag after 6h at the condition of electrify. It may because that lithium slag and cement hydration product can have secondary hydration in a short time, translating the loose Ca(OH)\(_2\) crystal which grow in concrete interface in specific direction into compact gelling layer. Thus give a rise to higher resistance of ion infiltrating, improving the concrete chloride-penetration resistance significantly.

![Fig 3. The effects of lithium slag on concrete chloride-penetration resistance](image)

3.4. The effects of lithium slag on the wear resistance of concrete
The test results of wear resistance of concrete can be seen in Fig.4. It shows that with the increasing of lithium slag mixing amount, the wear loss decreased first and then increased. Although the mixing amount of lithium slag reaches 30%, the wear loss of L3 lithium slag concrete is still less than L0
concrete without lithium slag. It may due to that adding lithium slag can improve the water retention and cohesiveness which increase the compactness of concrete. On the other hand, lithium slag can have secondary hydration with the production of cement hydration which also increases the compactness of concrete, improving the wear resistance. However, when the mixing amount of lithium slag is more than 20%, the wear resistance of lithium slag concrete will show decreasing trend. It is because with the increasing of lithium slag, the relevant hydration products will reduce. As lithium slag itself cannot hydrate, residual lithium slag can only fill in the concrete, making the compactness of concrete shows decreasing trend. Thus, it can decrease the improvement effect of lithium slag to compactness of concrete.

![Graph](image)

**Fig 4.** The effects of lithium slag on the wear resistance of concrete

### 3.5. Effects of Lithium Slag on the interfacial microstructure of Cement Concrete

![SEM images](image)

**Figure 5.** SEM image of interfaces of L0 on 28d

**Figure 6.** SEM image of interfaces of L1 on 28d

Fig.5 and Fig.6 are SEM images of interfaces of cement concrete without lithium slag and with 10% lithium slag respectively on 28d. As shown in Fig.5, without lithium slag, the interfaces of cement concrete appeared a lot flocculent C-S-H gels accompanied much acicular ettringite. As depicted in Fig.6, the interface structure of cement concrete with 10% lithium slag is much tighter. The hydration product mainly is flat C-S-H gels. The amount of ettringite was significantly decreased compared with the cement concrete without lithium slag. There was few ettringite in sample in Fig.6. It shows that the cement mixed with lithium slag consume more Ca(OH)₂ and reduce the production of ettringite due to the pozzolanic effect.[9]. Meanwhile, as a result of the adding of lithium slag, the amounts of C-S-H
gels increased and the density of cement concrete was improved which was important reasons of strengthening cement concrete.

4. Conclusion
Dry contractibility, abrasion resistance and chloride-penetration resistance of concrete can be improved by adding lithium slag but the abrasion resistance presents the downward trend when adding over 20% lithium slag into the concrete.

Adding lithium slag has negative effect on carbonation resistance of concrete and the carbonation resistance of concrete decreases gradually with the increasing amount of the lithium slag.

Adding lithium slag can enhance the density of the concrete and inhibit the formation of ettringite, meanwhile, it also can improve the concrete chloride-penetration resistance so that dry shrinkage performance, abrasion resistance and chloride-penetration resistance of concrete enhanced obviously.

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