물리적으로 활성화된 플라이애쉬를 함유한 시멘트 및 복합체의 이산화탄소 배출량 평가

Strength-based Evaluation of CO_2 Emission for Cement and Composite Containing Mechanically Sctivated Fly Ash

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Abstract

Fly ash, has been widely used as one of the main supplementary cementitious materials (SCMs) in the world, to replace part of cement to significantly save energy and reduce greenhouse emission. Via mechanical activation, fly ash can replace more cement without impairing early age compressive strength. This study focuses on the strength-based evaluation of carbon dioxide emission for blended cement composite containing mechanically activated fly ash. Results indicate that under similar compressive strength, a prominent drop has been witnessed in embodied energy of binary cement and CO2 emission of the composite containing mechanically activated fly ash compared with those containing ordinary fly ash.

키 워 드 : 플라이 애쉬, 시멘트 복합체, 물리 작용, 이산화탄소
Keywords : fly ash, cement composite, mechanical activation, carbon dioxide

1. Introduction

Fly ash is usually added into concrete to save energy and decrease carbon dioxide emission. However, the early-age compressive strength will be impaired by fly ash addition. Mechanical activation, is to directly decrease fly ash particle size by grinding and increase its surface area to improve fly ash reactivity in the fly ash-cement system. Mechanical activation can simultaneously increase early-age and later-age strength, However, what worries some researchers and industrialists is the cost, energy input, and greenhouse emission. via mechanical activation, fly ash is transformed to ultrafine fly ash. This process requires energy input and releases carbon dioxide. When activated fly ash is blended with cement, the performance of cement-based materials will be improved. Therefore, much more cement can be replaced to keep its initial performance. This process reduces carbon dioxide emission due to the decrease of cement amount. Besides, the performances of cement-based materials containing fly ash are directly related to the particle size or specific surface area of fly ash. The relationship between the degree of mechanical activation and performance/carbon dioxide emission is still lacking. In this study, strength-based life cycle carbon assessment considering mechanical activation. The calculation results about the effect of replacement ratio and mechanical activation on embodied energy, compressive strength, and carbon dioxide emission for binary cement or composite containing fly ash are analyzed and discussed.

2. Methods

Under the same compressive strength, the calculation methods related to the embodied energy of fly ash cement and the CO_2 emission of composite will be evaluated.

3. Results and Discussion

Group 1 is Portland cement composite without fly ash. When 15% cement is replaced by ordinary fly ash, com-

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pressive strength at 28 days and 56 days of group 2 are lower than that of group1, which indicates that cement composite containing ordinary fly ash at an early age cannot improve early age compressive strength. Via calculation, when 28% cement is replaced by ultrafine fly ash, the 28-day compressive strength of group 4 is similar to that of group 2. Evidently, more cement is replaced by ultrafine fly ash without impairing compressive strength. After curing 56 days, the compressive strength of group 4 is slightly higher than that of group 2 and much higher than that of group 1 mainly because of the pozzolanic effect of ultrafine fly ash. Much more gel is produced by the pozzolanic reaction and capillary pores are densified with the curing time, which is responsible for the strength improvement.

The embodied energy of binary cement has dropped from 0.931 to 0.757 kg CO_2/kg cement at the cost of reducing early age compressive strength. CO_2 emission of composite has decreased from 499.28 to 422.20 kg CO_2/m^3, and the greenhouse emission reduction ratio reaches 15%. Interestingly, when 15% cement is substituted by mechanically activated fly ash, there is no significant growth for embodied energy and CO_2 emission of group 3 compared with those of group 2. Similar results are also observed between group 4 and group 5. However, the early-age compressive strength of group 3 (or group 5) has increased and is much higher than that of group 2 (or group 4). This indicates that mechanical activation will not contribute to CO_2 emission too much, but it will drastically improve strength. It has to be noted that group 4 and group 2 have similar 28-day and 56-day compressive strength, but group 4 dramatically decreases the embodied energy from 0.757 to 0.680 kg CO_2/kg cement and CO_2 emission of the composite from 422.20 to 357.93 kg CO_2/m^3 composite.

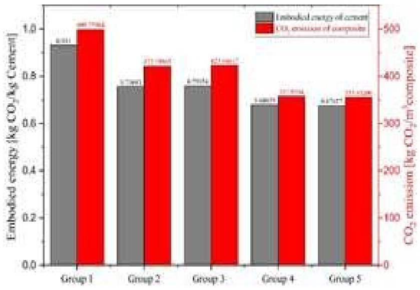

Figure 1

Group	Cement (kg/m³)	FA (kg/m³)	UFA (kg/m³)	Sand (kg/m³)	Water (kg/m³)	FA replacement ratio	f_{c28} (MPa)	f_{c56} (MPa)
1	534	-	-	1603	214	0	51.97	53.39
2	449	106	-	1585	212	15%	49.91	51.76
3	449	-	106	1583	212	15%	54.06	58.11
4	377	-	146	1571	210	28%	49.82	54.64
5	377	146	-	1571	210	28%	44.60	47.18

Table 1

4. Conclusion

Compared with ordinary fly ash, mechanically activated fly ash can replace more cement without loss of early-age compressive strength. Under similar compressive strength, both the embodied energy of binary cement and the CO2 emission of the composite containing mechanically activated fly ash have significantly decreased compared with those containing ordinary fly ash.

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References

1. Vargas J, Halog A, Effective carbon emission reductions from using upgraded fly ash in the cement industry[J]. Journal of Cleaner Production, Vol.103, pp.948~959, 2015