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Composition of iron ores from Mongolian western region and its applicability for cement production

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Abstract: In this research were studied the chemical and mineral compositions of some iron ores in Mongolian the western region. Also the study investigated the effect of calcium fluoride on decomposition temperatures of calcite in the raw mixfor obtaining cement clinker.

The chemical investigation result showed that iron oxide (Fe_2O_3) content in the western Mongolian iron ores represents in Uvgondatsan (Khovd) – 87.23%, Suul Khar (Khovd) – 85.00% and Kharganat (Uvs) – 89.29%, respectively. Iron ores of Kharganat and Uvgundatsan are mostly contained magnetite (Fe_3O_4) while iron ore of Suul Khar is mostly contained hematite (Fe_2O_3).

The decomposition temperature of calcite ($CaCO_3$) was reduced by 5°C, 10°C, and 15°C when calcium fluoride (CaF_2) in the raw mix for obtaining cement clinker that consists of Shokhoit limestone, Shal clay and Kharganat iron ore was added up 0.5%, 1.0% and 1.5% .

Keywords: Iron ore, magnetite, hematite, saturation coefficient, raw mix for obtaining cement clinker.

INTRODUCTION

Iron ore is mineral that contains high Fe_2O_3 and mixture of alumosilicates. In order to reduce module of alumina in cement production, minerals that have high iron content are used [1, 2]. Iron ore generally comprised minerals such as magnetite ($Fe_2O_3\cdot FeO$), hematite (Fe_2O_3), limonite (β- FeO(OH)), goethite (α-FeO(OH)), lepidocrocite (γ-FeO(OH)), siderite ($FeCO_3$) and ilmenite ($FeTiO_3$). According to geological search in Mongolia, approximately 200 iron ore mines were discovered. Main objective of the study is to determine chemical and mineral composition of the Western Mongolian iron ores and to investigate possibilities to use their in raw mix for obtaining cement. Chemical pure calcium fluoride (CaF_2) is used in order toresearch effect of mineralizing agent ondecomposition temperature of calcite in raw mix for obtaining cement clinker.

EXPERMENTAL

Iron ores from Kharganat in Uvs aimag and Suulkhar, Uvgundatsan in Khovd aimag, and chemical pure calcium fluoride were used in this research. Kharganat iron ore deposit is located 45 km northwest from center of Naranbulag soum and 3.2 km from the lake Sharburd. The deposit length is 1200 m and width is 12-30 m. The geographic coordinates of Kharganat iron ores are $49^{\circ}37'00''$ (north latitude) and $92^{\circ}11'00''$ (east longitude). Uvgundatsan iron ore is located 105 km from Khovd city and 60 km northwest from Myangad soum. The geographic coordinates of Uvgundatsan iron ores are $48^{\circ}24'24''$ (north latitude) and $91^{\circ}51'00''$ (east longitude).

SuulKhar iron ore is located 22 km from Khovd city and 45 km from Buyant soum. The geographic coordinates of Suulkhar iron ores are $47^{\circ}51'00''$ (north latitude) and $91^{\circ}48'00''$ (east longitude).

We used by standard method for taking and preparing samples. Mineral composition of raw materials determined by X-Ray diffraction (XRD) and Thermal analysis (TG/DTA), chemical composition determined byenergy disperse X-Ray fluorescence (ED -XRF,MESA 500W) analysis and calculation of cement raw mixture by Kinds method [1 - 3].

TG/TDA measurements were undertaken with Derivatograph T-1500, Hungary, Thermo analyzer at a heating rate of 10°C/min using α-Al_2O_3 as a reference material.

X-ray diffraction (XRD) analysis was conducted using by DRON-2 tool with iron cathodes and voltage of X-ray tube at 30kV and 20 mA, width of slot at 1×10/0.25×6. Minerals were identifiedusing ASTM card and directory.

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RESULTS AND DISCUSSION

Chemical composition of iron ores: The chemical composition of iron ores determined using by energy disperse X-ray fluorescence (ED-XRF) analysis. Results are shown in the Table 1.

Table1. Chemical composition of iron ores, %

Iron ores	SIO_2	Al_2O_3	Fe_2O_3	CaO	Mn_2O_3	MgO	SO_3	Na_2O	K_2O	LOI	S
1*	7.07	1.02	89.29	0.53	=	0.15	1.02	1.02	0.01	=	100.
2*	9.684	1.164	87.227	1.408	0.129	=	=	=	=	1.18	99.995
3*	3.945	0.671	85.002	0.485	=	0.001	=	0.003	0.004	9.88	100.001
4*	8-20	0.5-4	58-74	1.8-6	=	3.5-7	2-7	8.5-20	0.5-3.6	2-7	=

1* - Kharganat (Uvs), 2* - Uvgundatsan (Khovd), 3*- Suul Khar (Khovd), 4* – Tumurt [4]

From Table 1 can be seen that the contents of iron oxide (Fe_2O_3) in the Western Mongolian iron ores such as Kharganat, Uvgundatsan, SuulKhar are higher than it is in Tumurt (4) iron ore which is presently used in cement production.

Mineral composition of iron ores: DTA/TG studies: Mineral composition of iron ores were investigated by using TDA analysis. The results are shown in the Figure 1 - 3.

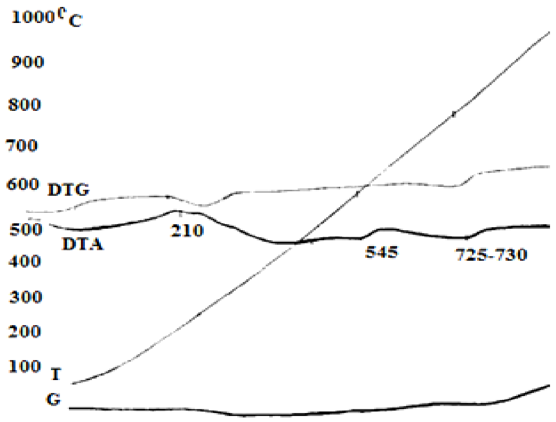

Fig. 1. DTA/TG curves of the Kharganat iron ore

From Fig. 1 we can see that: A small amount of heat was emitted due to thewater evaporation in β-limonite [β -FeOOH) as same as β-$Fe_2O_3 \cdot H_2O$] at the 210^{0}C. At this region, sample weight was reduced by Δm= - 4.5mg ~0.3% and it can be calculated from weight loss curve. Content of β-limonite within this iron ore is 2.97% [5], the reaction transformation of β -limonite decomposeto $Fe_2O_3$by the following equation:

$$\beta\text{-}Fe_2O_3 \times H_2O \rightarrow \beta\text{-}Fe_2O_3 + H_2O$$

From above reaction, content of iron oxide within Limonite to be calculated 2.69%.

Heat absorption was observed due to the γ-iron oxide (γ-Fe_2O_3) in composition of lepidocrocite (γ-FeOOH) as same as γ-$Fe_2O_3 \times H_2O$) transformed into a-hematite (a-Fe_2O_3) at 545^{0}C. At this region, sample weight was reduced by Δm = -3.0 mg ~ 0.2% and it can be calculated from weight loss curve. Content of Lepidocrocite within this iron oreamount to 1.97%, and the reaction transformation of lepidocrocite to Fe_2O_3can be seen by the following equation:

$$\gamma\text{-}Fe_2O_3 \cdot H_2O \rightarrow \gamma\text{-}Fe_2O_3 + H_2O$$

From above reaction, content of iron oxide within Lepidocrocite to be calculated 1.78%. Heat absorption was occurred due to transformation of a-hematite into β-hematite at 725^{o}C. In this transformation region of phase, sample weight was increased by Δm = 19mg ~ 1.27%. The reason is that, during the process of α-Fe_2O_3 to β-Fe_2O_3, density is increased from 3.3 mg/cm^3 to 4.28 mg/cm^3 [5].

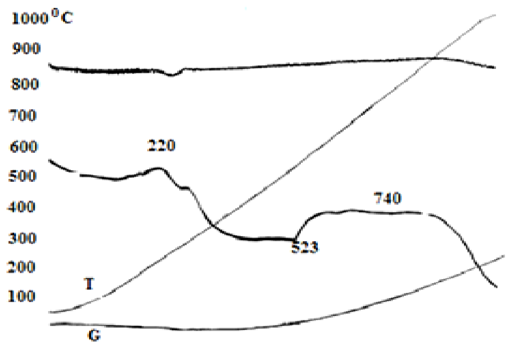

Fig. 2. DTA/TG curves of the Uvgundatsan iron ore.

From Fig. 2, we can see that: A small amount of heat was emitted due tothewater evaporation in β-Limonite [β -FeO(OH) as same as β-$Fe_2O_3 \times H_2O$] at the 220^{0}C. At this region, sample weight was reduced by Δm= - 4mg ~ 0.2% and it can be calculated from weight loss curve. Content of limonite this iron ore amount to 1.97%. Reaction transformation of β-limonite to β-Fe_2O_3can be seen by the following equation:

$$\beta\text{-}Fe_2O_3 \times H_2O \rightarrow \beta\text{-}Fe_2O_3 + H_2O$$

From above reaction, content of iron oxide within Limonite was calculated 1.78%. Heat absorption was observed due to the γ -iron oxide (γ-Fe_2O_3) in composition of lepidocrocite (γ-FeOOH) as same as γ -Fe_2O_3 × H_2O) transformed into a-hematite (a-Fe_2O_3) at 523^{0}C. At this region, sample weight was reduced by Δm= -3mg ~0.15% and it can be calculated from weight loss curve. Content of lepidocrocite within this iron oreamount to 1.48% and the reaction transformation of lepidocrocite to Fe_2O_3can be seen by the following equation:

$$\gamma\text{-}Fe_2O_3\cdot H_2O \rightarrow \gamma\text{-}Fe_2O_3 + H_2O$$

From above reaction, content of iron oxide within Lepidocrocite was calculated 1.33%. Heat absorption was occurred due to transformation of α-hematite into β-hematite at 740^{o}C. In this transformation region of phase, sample weight was increased by Δm=25mg~1.25%. The reason is that, during the process of α-Fe_2O_3 to γ-Fe_2O_3, density is increased from 3.3mg/cm^3 to 4.28mg/cm^3.

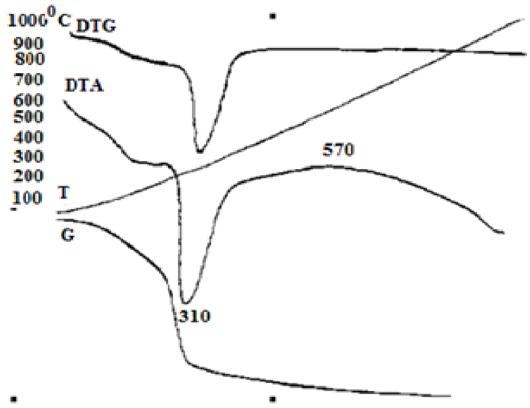

Fig. 3. DTA/TG curves of the SuulKhar iron ore.

From Fig.3, we can see that, the deep endotherm peak was formed due to the hydro-hematite water evaporation at the 310^{o}C. At this region, sample weight was reduced by Δm=110mg ~ 7.38% and it can be calculated from weight loss curve. Content of hydro-hematite amount to72.98%, and the reaction transformation hydro-hematite to Fe_2O_3 can be seen by the following equation:

$$Fe_2O_3 \; X \; H_2O \rightarrow \text{-}Fe_2O_3 + H_2O$$

From above reaction, content of iron oxide within hydro-hematite to be calculated 65.6%. An exothermic effect was occurred due to process of γ-Fe_2O_3 to α-Fe_2O_3 in magnetite compositionat 570^{0}C. In this transformation, sample weight was reduced by m=-14mg~0.9395%. The reason is that, during the process sample density was decreased from 4.28mg/cm^3 to 3.3mg/cm^3.

X-ray studies: X-ray diffraction (XRD) analysis was conducted using by DRON-2 tool, results are shown in the Figure 4 - 6.

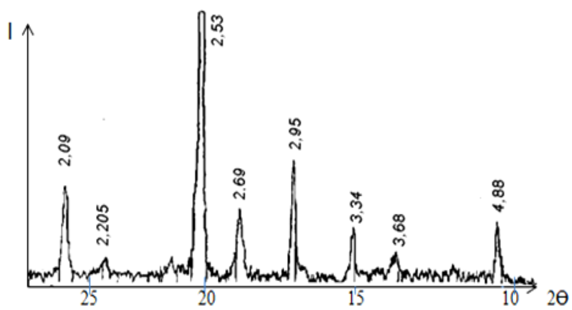

Fig. 4. X-ray diffractogram of Kharganat iron ore

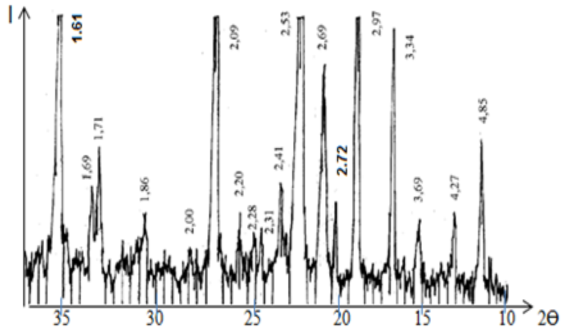

Fig. 5. X-ray diffractogram of Uvgundatsan iron ore

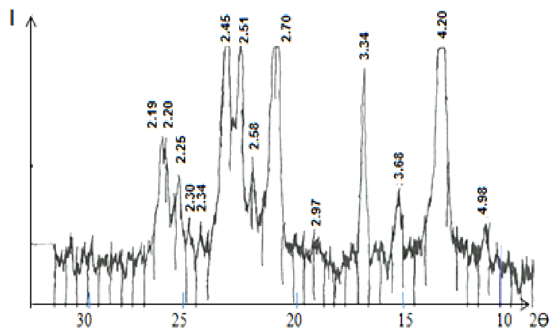

Fig. 6. X-ray diffractogram of SuulKhar iron ore

The Figure 4 showed that there are high intensity diffraction line of magnetite at d=2.53A^0, medium intensity magnetite lines at d=2.95; 2.09Å, medium and low intensity diffraction lines of hematiteat d=4.88; 3.68; 2.69; 2.205 Å and low intensity diffraction line of quartz at d=3.34 Å. In the Figure 5, presents high and medium intensity diffraction lines of magnetite at d=4.85, 2.97, 2.72, 2.53, 2.41, 2.09, 1.71, 1.61Å, low intensity diffraction lines of hematite at d=3.69, 2.69, 2.31, 2.20, 1.86, 1.69Å, high and low intensity diffraction lines of quartz at d=4.27, 3.34, 2.00, 2.28, 2.70 Å. In the Figure 6, were observed high and medium intensity diffraction lines of magnetite at d=2.97, 2.51, 2.45Å, medium and low intensity diffraction lines of hematite at d=3.68, 2.58, 2.30, 2.20, 2.19Å, high and low intensity diffraction line of quartz at 4.20, 3.34, 2.30Å [6, 7].

The results of mineral analysis showed that iron ores of Kharganat and Uvgundatsan are mostly contained magnetite (Fe_3O_4), whereas iron ore of SuulKhar is the mostly contained hematite (Fe_2O_3).

The research result of the effect of calcium fluoride on decomposition temperature of calcite in raw mix for obtaining cement: A calculation raw mix for obtaining cement clinker that consists of Shokhoit limestone, Shal clay and Kharganat iron ore was calculated by Kinds method. Silica module was n=2.2 while saturation coefficients (SC) were at 0.83, 0.88 and 0.93 in this calculation. The results are shown in the Table 3 and chemical composition of the initial materials [8] which used for making raw mixes is shown in the Table 2.

Table 2.Chemical composition of raw material, %

Name of raw material	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	Mn_2O_3	other	LOI	S
Limestone (Shokhoit)	0.85	0.10	0.25	54.64	0.25	0.20	0.22	-	-	0.62	42.87	100
Clay of Shal	58.33	15.4	3.12	5.13	3.58	0.22	2.7	2.89	-	0.298	8.33	100
Iron ore of Kharganat	7.07	1.02	89.29	0.53	0.15	1.02	1.02	0.01	-		-	100.1
Iron ore of Uvguntsan	9.684	1.164	86.435	1.408	-	-	-	-	0.129		1.18	100
Iron ore of Suulkhar	3.945	0.671	85.002	0.485	0.001		0.003	0.004	-		9.89	100.0

Table 3. Composition and characteristics of mixes for obtaining cementclinkers

Mix	Component content, (mass. %)			SC	Modules	
	Lime stone	Clay	Iron ore		SM	AM
A-1	73.90	23.98	2.23	0.83	2.2	1.3
A-2	75.17	23.05	2.15	0.88	2.2	1.29
A-3	75.73	22.20	2.07	0.93	2.2	1.31
B-1	73.80	23.86	2.32	0.83	2.2	1.29
B-2	74.80	23.86	2.24	0.88	2.2	1.29
B-3	75.77	22.11	2.16	0.93	2.2	1.25
C-1	73.66	24.02	2.32	0.83	2.2	1.29
C-2	74.65	23.11	2.23	0.88	2.2	1.26
C-3	75.60	22.26	2.15	0.93	2.2	1.3

Mix A was calculated from Kharganat iron ore, mix B was calculated from Uvgudatsan iron ore and mix C was calculated from Suulkhar iron ore

According to the result of raw material evaluation, it can be observed that amounts of iron ore in 100 kg cement are approximate for every saturation coefficient level and modules (Table 3) in clinker composition are within the limit of Portland cement standard [9]. In conclusion, it could be assumed that these iron ores can be used in cement production.

Research was conducted as follows: Calcium fluoride at 0%, 0.5%, 1.0% and 1.5% of raw material weight were added up to limestone of Shokhoit, clay from Shal and iron ore of Kharganat at saturation coefficient of SC=0.93 and silica module at n = 2.2 (Table 4).

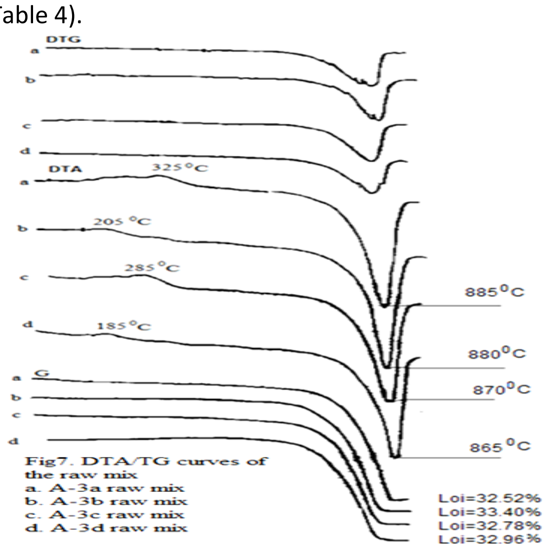

Fig. 7. DTA/TG traces of mixtures with CaF_2 addition

Table 4. Composition of raw mixes with addition CaF_2

Mix	Amount of mix, (m. %)	
	Amount of initial mix, (m. %)	Addition CaF_2, (m. %)
A-3a	100	=
A-3b	99.5	0.5
A-3c	99	1.0
A-3d	98.5	1.5

The effect of calcium fluoride on decomposition temperature of calcite in raw mix for obtaining cement we determined by DTA analysis. Result is shown in Figure 7.

In Figure 7 was observed weak exothermic effect due to the water evaporation of clay minerals in raw material composition at 325 - 185^{0}C, deep endotherm peak was observed due to the decomposition of calcite ($CaCO_3$), which is the main component of composition, at 865 - 870^{0}C.

The sample weight loss was 32.52% without calcium fluoride, the loss was 33.4% when calcium fluoride was added 0.5% while it was 1.0% the loss was 32.78%, and when it was 1.5% the loss was 32.96%.

From Fig. 7 we can see that, the decomposition temperature of calcite ($CaCO_3$) was reduced by 5^{o}C, 10^{0}C, and 15^{0}C when up 0.5%, 1.0% and 1.5% calcium fluoride (CaF_2) was added in the raw mix for obtaining cement clinker that consists of Shokhoit limestone, Shal clay and Kharganat iron ore.

CONCLUSIONS

Based on the studies, the following conslusions can be drawn:

- The chemical investigation result showed that iron oxide (Fe_2O_3) content in the Western Mongolian iron ores represents up to Uvgondatsan (Khovd) – 87.23%, Suulkhar (Khovd) – 85.00% and Kharganat (Uvs) – 89.29%, respectively. Therefore, these iron ores can be used in cement production.
- X-ray diffraction and DTA analysis results show that their on ores of Kharganat and Uvgundatsan deposits mostly contained magnetite (Fe_3O_4) while iron ore of SuulKhar deposit mostly contained hematite (Fe_2O_3).
- A calculation of raw mix for obtaining cement clinker was done by using iron ores, clay of Shal and limestone of Shokhoit. Calculated modules of clinker composition (n=2.2, p=1.25-1.30) are within the limit of Portland cement standard.
- The decomposition temperature of calcite ($CaCO_3$) was reduced by 5^0C, 10^0C, and 15^0C when calcium fluoride (CaF_2) added in the raw mix for obtaining cement clinker with amount of up 0.5%, 1.0% and 1.5%, respectively.

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