

急乾燥がキャストブルの諸特性に与える影響

Influence of Rapid Drying on Properties of Castables

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Abstract

Unshaped refractories are widely used for various places and functions. Appropriate curing and drying conditions are necessary for good construction. Rapid drying causes explosive spalling in the worst case and it can produce high pressure water vapor which causes cracking.

A rapid drying condition was determined from the result of the explosive spalling test, and rapid dry samples were made.

The properties of those samples were compared in order to study the influence of rapid drying on castables.

1. 緒言

不定形耐火物は、各所、各用途にて広く使用されているが、良好な施工体を得るためには、適度な養生、乾燥条件が必要である。急乾燥を行った場合、最悪のケースでは施工体が爆裂を起こしてしまうが、爆裂に至らない場合でも内部に高圧の水蒸気が発生するために微亀裂を発生させるなど施工体組織に変化をもたらしている可能性は十分に考えられる^{1)~3)}。しかし、この急乾燥が施工体へ与える影響について報告された例は少ない。

今回、緻密で影響を受けやすいと思われる低セメントキャストブルとしてアルミナ・マグネシア質取鍋用キャストブルを、爆裂しにくく影響を受けにくいと思われるキャストブルとしてアルミナ・シリカ質汎用キャストブルを取り上げ、急乾燥が施工体の品質に与える影響について調査した。

1. Introduction

Unshaped refractories are widely used for various places and functions. Appropriate curing and drying conditions are necessary for good construction. Rapid drying causes explosive spalling in the worst case, which causes cracking^{1)~3)}. But there are few reports about the influence of rapid drying on construction.

We studied the influence of rapid drying on the properties of alumina-magnesia ladle castables and alumina-silica utility castables.

2. Experiments

2. 1 Test samples

We used ladle castables and utility castables for this study. Table 1 shows the mix composition ratios of the test samples.

We tried alumina-magnesia ladle castable

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Table 1 Properties of castables

Sample No.		1	2	3	4	5
Chemical composition / mass%	Al ₂ O ₃	90	90	90	90	45
	MgO	7	7	7	7	-
	SiO ₂	1	1	1	1	47
Cement contents / mass%		3	5	7	9	18
Water content / mass %		5.6	5.6	5.6	5.6	13.0
V5 flow value / mm		201	207	193	187	245

2. 実験

2. 1 供試サンプル

供試サンプルとして取鍋材質と汎用材質を用いた。各配合組成をTable 1に示す。

緻密な低セメントキャストブルとして、取鍋材質 Al₂O₃ = 90mass%, MgO = 7 mass%, SiO₂ = 1 mass% のアルミナ・マグネシア質キャストブルを用いた。また、取鍋材質においてセメントによる影響を調査するため、セメント添加量を 3 ~ 9 mass% まで変化させた配合を用いた。なお、流動性がほぼ一定 (V5フロー値 ≒ 190 ~ 200mm) となるように添加水分量を設定し混練した。

爆裂しにくく、急乾燥に影響されにくいと思われる汎用材質には、Al₂O₃ = 45mass%, SiO₂ = 47mass% の流し込み用アルミナ・シリカ質キャストブルを用いた。添加水分量はV5フロー値が約 250mm になるように設定し混練した。

2. 2 試験項目および試験条件

①爆裂試験

サンプルが爆裂しない限界の急乾燥温度を設定するために爆裂試験を実施した。同じ材料で 80φ × 80mm の円筒形状と 40 × 40 × 160mm 形状のサンプルを鋳込み、養生条件は 35℃ - 24h に設定した。養生後曲げ強さは、40 × 40 × 160mm 形状サンプルにて測定し、爆裂テストは 80φ × 80mm サンプルにて行った。

爆裂試験は 100℃ ごとの設定温度にキープした

(Al₂O₃ = 90mass%, MgO = 7mass%, SiO₂ = 1 mass%) which is a dense low-cement castable. We changed the amount of the cement addition from 3 ~ 9mass% to study the influence of cement content in ladle castables. The amount of water addition was set so that the flowability would be constant (V5 flowability ≒ 190 ~ 200mm).

We tried Alumina-silica utility castable (Al₂O₃ = 45mass%, SiO₂ = 47mass%). It seemed not to be easily influenced by the rapid drying and not to explosively spall easily. The amount of water addition was set so that flowability would be V5 flow value = 250mm.

2. 2 Examination term and testing conditions

①Explosive spalling test

An explosive spalling test was conducted to determine the highest limit of the rapid drying temperature at which explosive spalling does not occur. Samples of 80φ × 80mm and 40 × 40 × 160mm were made of the same material. The curing conditions were set at 35℃ - 24h.

After curing, the M.O.R of the 40 × 40 × 160mm sample was measured. The explosive spalling test was done with the 80φ × 80mm samples. After curing, 80φ × 80mm sample was placed in a preheated electric furnace to confirm whether the sample caused explosive spalling or not. The maximum temperature at which explosive spalling did not occur was assumed to be the explosive spalling temperature limit of the sample.

②Rapid drying test

40 × 40 × 160mm samples were made with each mix. The following Conditions a-c were used to study the influence of rapid drying on the properties of the castables. Condition c was the most severe heat up condition among Conditions a, b and c.

電気炉内へ養生後の $80\phi \times 80\text{mm}$ サンプルを投入し、爆裂の有無を確認した。このとき爆裂しない最高温度をそのサンプルの爆裂限界温度とした。

②急乾燥が品質特性に与える影響調査試験

各配合を $40 \times 40 \times 160\text{mm}$ 形状に鋳込み、急乾燥による影響を調べるため以下の条件 a～c を設定しサンプルを作成した。a, b, c の順に急昇熱の条件となっている。

- a) $35^\circ\text{C} - 24\text{h}$ 養生後, $105^\circ\text{C} - 24\text{h}$ で乾燥し, $1000^\circ\text{C} - 3\text{h}$ で加熱
- b) $35^\circ\text{C} - 24\text{h}$ 養生後, 500°C に昇温した電気炉に投入し, そのまま $1000^\circ\text{C} - 3\text{h}$ で加熱
- c) $35^\circ\text{C} - 24\text{h}$ 養生後, 各サンプルの爆裂限界温度 (爆裂試験で測定) $- 100^\circ\text{C}$ に昇温した電気炉に投入し, そのまま $1000^\circ\text{C} - 3\text{h}$ 加熱

Fig. 1にサンプル作成手順と養生および加熱条件, Fig. 2に各条件の電気炉投入温度, 電気炉の昇温パターンを示す。

電気炉の昇温パターンは $5^\circ\text{C}/\text{min}$ で 1000°C まで昇温し, そのまま 1000°C で3時間キープし, その後大気温度までゆっくりと冷却を行った (Fig. 2)。冷却後のサンプルにて曲げ強さ・圧縮強さ・見掛気孔率・嵩比重・弾性率の測定を行った。

これらのサンプルを比較することで急乾燥が品質に与える影響を調査した。

③回転るつば侵食試験

急乾燥の影響が耐食性に及ぼす影響を調査した。配合 3 を用いて $80 \times 30 \times 20\text{mm}$ の形状のサン

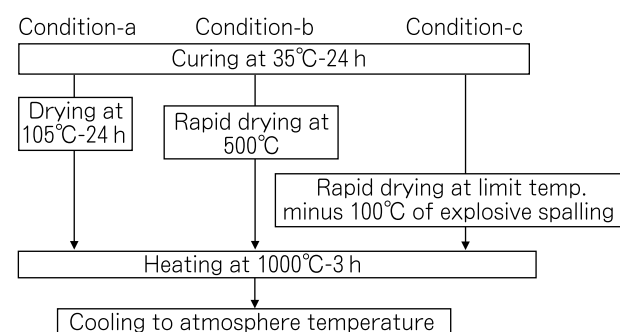


Fig. 1 Experimental procedure for rapid drying.

- a) After curing at $35^\circ\text{C} - 24\text{h}$. Drying $105^\circ\text{C} - 24\text{h}$ and heating at $1000^\circ\text{C} - 3\text{h}$.
- b) After curing at $35^\circ\text{C} - 24\text{h}$. Rapid drying at 500°C in an electric furnace. Then heated up to 1000°C and kept at $1000^\circ\text{C} - 3\text{h}$.
- c) After curing at $35^\circ\text{C} - 24\text{h}$. Rapid drying at 100°C below the explosive spalling temperature limit (measured by the explosion examination). Then heated up to 1000°C and kept at $1000^\circ\text{C} - 3\text{h}$.

Fig. 1 shows the experimental procedure for rapid drying. Fig. 2 shows the heating up profile of the rapid drying test. The temperature was raised to 1000°C at $5^\circ\text{C}/\text{min}$, and was kept at 1000°C for three hours. After that, it was cooled down to atmospheric temperature slowly (Fig. 2). We measured the M.O.R, crushing strength, apparent porosity, bulk density and modulus of elasticity with these samples.

We studied the influence of rapid drying on the castables properties by comparing the results of the measurements.

③Corrosion test

The influence that rapid drying exerted on corrosion resistance was investigated. After

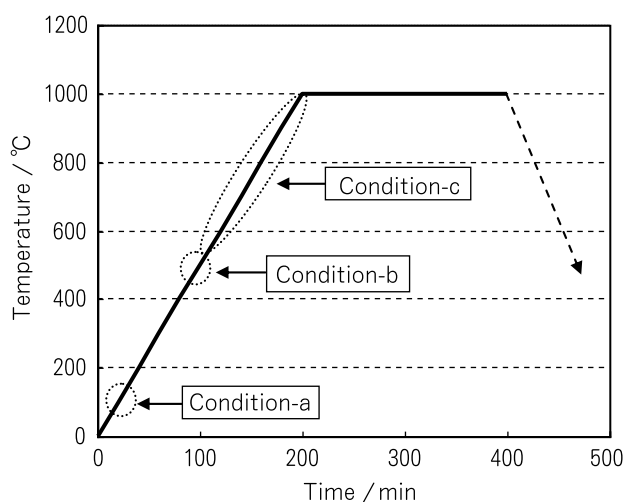


Fig. 2 Heat up profile of rapid drying test.

Table 2 Results of explosive spalling test

Sample No.	1	2	3	4	5
Cement contents / mass%	3	5	7	9	18
M.O.R after curing / MPa	0.82	1.21	1.64	2.08	6.96
Results of explosive spalling test	○600℃	○900℃	○900℃	○1000℃	○1000℃
	×700℃	×1000℃	×1000℃	—	—

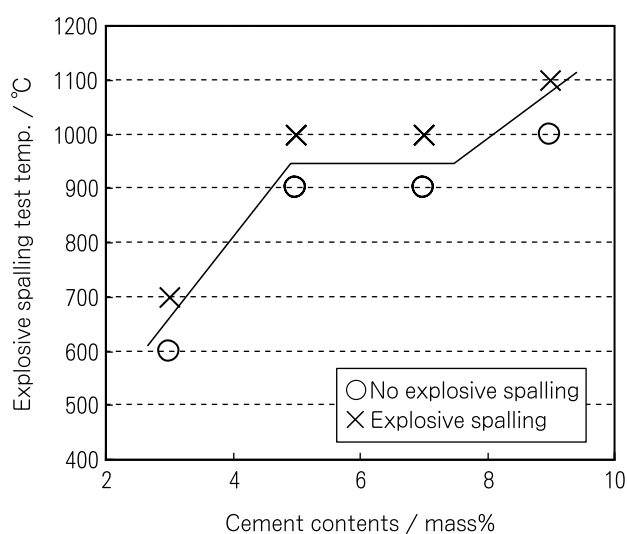


Fig. 3 Effect of cement content on explosive spalling.

プルを4枚作成した。35℃-24h養生したサンプルを条件 a, b, c および300℃で急乾燥した。侵食試験の条件は熱源に酸素プロパンバーナーを用い1650℃-3h加熱し、スラグはC/S=3.3の転炉スラグを使用した。

3. 結果

3.1 爆裂試験結果

35℃-24h養生後の爆裂試験結果をTable 2に示す。

取鍋材質配合においてはセメント添加量が多くなるほどに耐爆裂性の向上傾向が見られた。

試験結果から、セメント量と耐爆裂性の関係をFig. 3に示す。

curing at 35℃-24h and Rapid drying under conditions a, b and c, 80×30×20mm samples were made with sample 3. The samples were heated to 1650℃-3h with an oxygen propane burner, and converter furnace slag C/S=3.3 was used.

3. Results

3.1 Explosive spalling test results

The explosive spalling test results after curing at 35℃-24h are shown in Table 2.

Improved tendency for explosive spalling resistance was seen by increasing the amount of cement content in the ladle material.

The relation between the amount of cement content and explosive spalling resistance is shown in Fig. 3.

It was confirmed that the explosive spalling temperature limit rose according to the increase in the amount of cement content.

We studied the influence of rapid drying on the castable properties by finding the explosive spalling temperature limit of each sample confirmed by explosive spalling test.

3.2 Influence of rapid drying the castable properties

The properties of the samples made under conditions a, b, and c were measured to study about the influence of rapid drying on castables the properties. In Fig. 4 to Fig. 8 the Y axis

セメント量の増加に従い爆裂限界温度が高くなることが確認された。

今回の爆裂試験で確認された各サンプルの爆裂限界温度を用いて急乾燥による品質への影響を調査した。

3.2 急乾燥による品質への影響

急乾燥の影響を調査するため、条件 a, b, c で作成したサンプルの品質を測定した。

Fig. 4に曲げ強さ、Fig. 5に圧縮強さ、Fig. 6に見掛気孔率、Fig. 7に嵩比重、Fig. 8に弾性率の測定結果を示す。各品質の値をY軸に、電気炉投入温度をX軸に設定している。

①曲げ強さ

500℃急乾燥を行った取鍋材質では、セメント 3 mass%では強度低下は見られなかったが、セメント 5, 7, 9 mass%の配合では強度低下が見られた。しかし、汎用材配合5ではセメントは 18mass%と取鍋材質と比較して多いが強度低下は認められなかった。

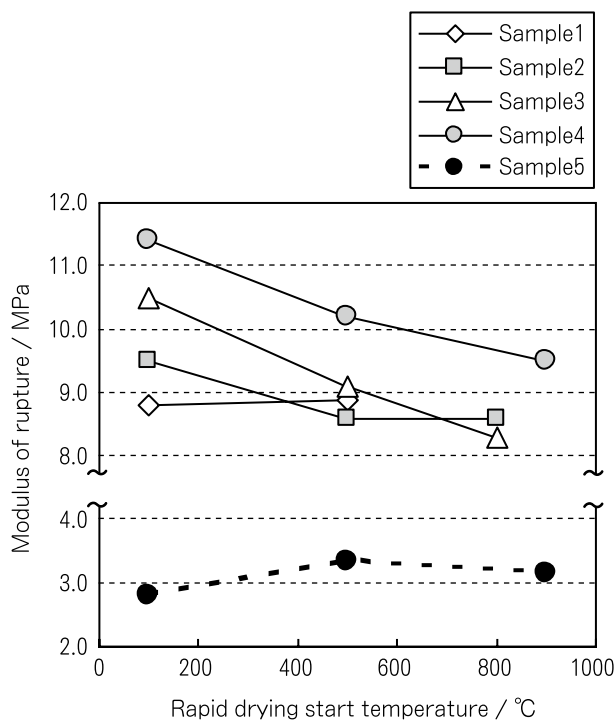


Fig. 4 Modulus of rupture after 1000°C-3h heating with rapid drying.

represents various measured qualities. And the X axis represents the temperature at which the sample was put in the electric furnace.

The M.O.R results are shown in Fig. 4. The Crushing strength is shown in Fig. 5, the apparent porosity is shown in Fig. 6, the Bulk density is shown in Fig. 7, and the Modulus of elasticity is shown in Fig. 8.

① Modulus of rupture

After rapidly drying the ladle castable at 500℃. The deterioration of strength was examined according to cement contents of 5, 7 and 9mass%. Though deterioration of strength was not seen with a cement content of 3mass%. Deterioration of strength was not seen in utility castable sample 5 either, even though 18mass% cement was added (The cements contents are more than those of ladle castables).

Samples 2, 3, 4 and 5, with limiting explosive spalling temperatures of 500℃ or more, were rapidly dried. No deterioration of strength was seen in samples 2 (cement contents=5mass%) and 5 (Utility castable).

② Crushing strength

By rapidly drying the ladle castable at 500℃, a comparatively large deterioration of strength was seen in sample 3 (cement=7mass%) and some strength decrease was seen in the other ladle castable samples.

By rapid drying at 100℃ below the explosive spalling temperature limit, more deterioration of strength was seen in sample 2 (cement=5mass%) and 4 (cement=9mass%). No decrease in strength was seen in utility castable sample 5.

③ Apparent porosity

When the ladle castable was rapidly dried at 500℃, a decrease in apparent porosity was seen in sample 1 (cement=3mass%). And an increase

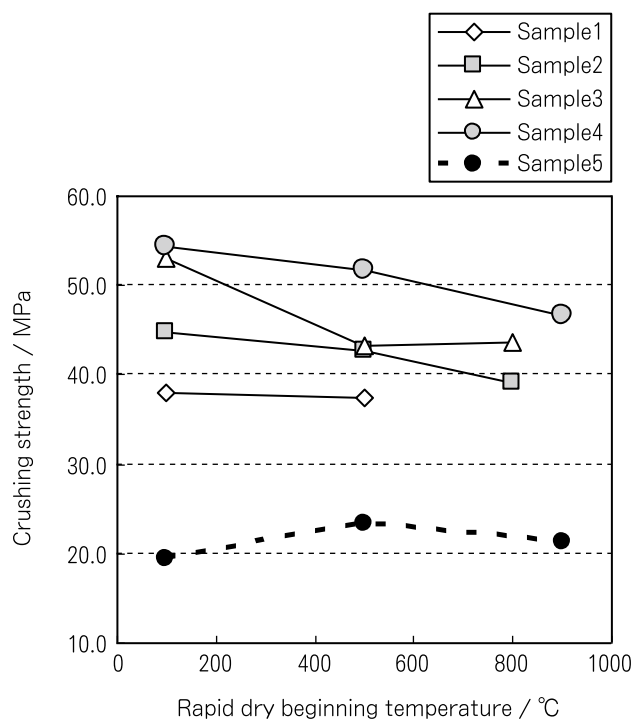


Fig. 5 Crushing strength after 1000°C-3h heating with rapid drying.

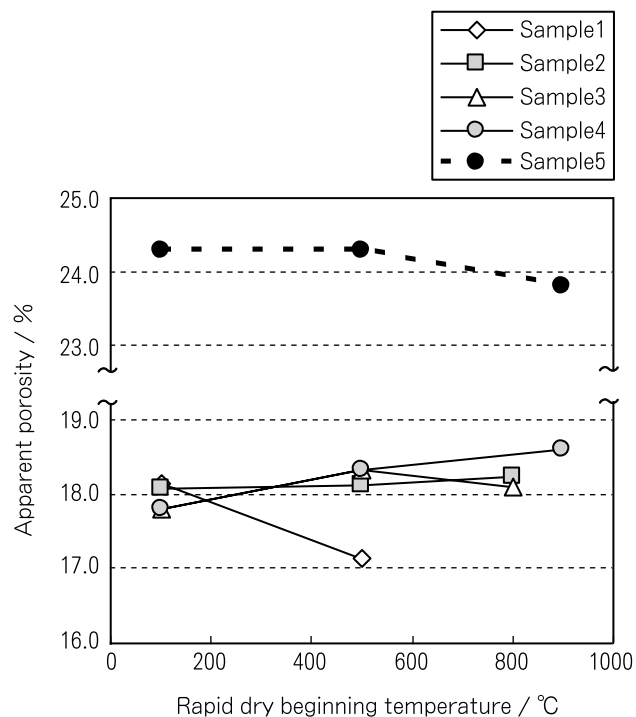


Fig. 6 Apparent porosity after 1000°C-3h heating with rapid drying.

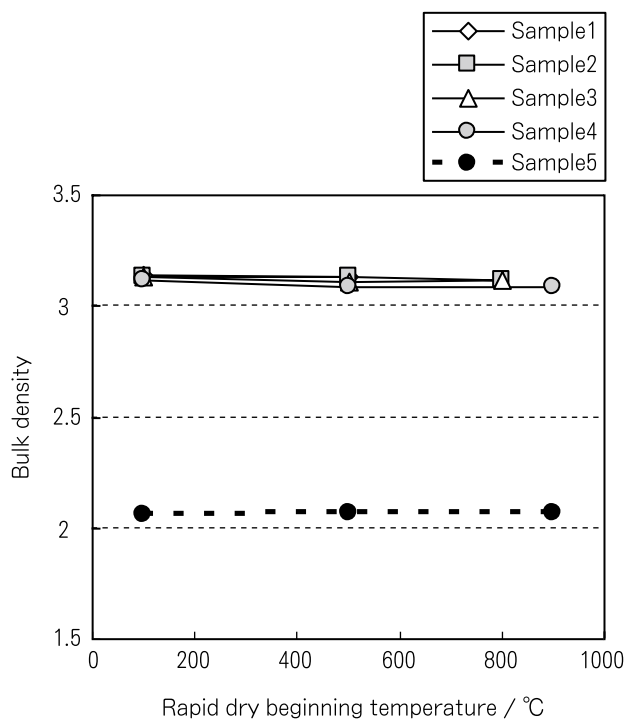


Fig. 7 Bulk density after 1000°C-3h heating with rapid drying.

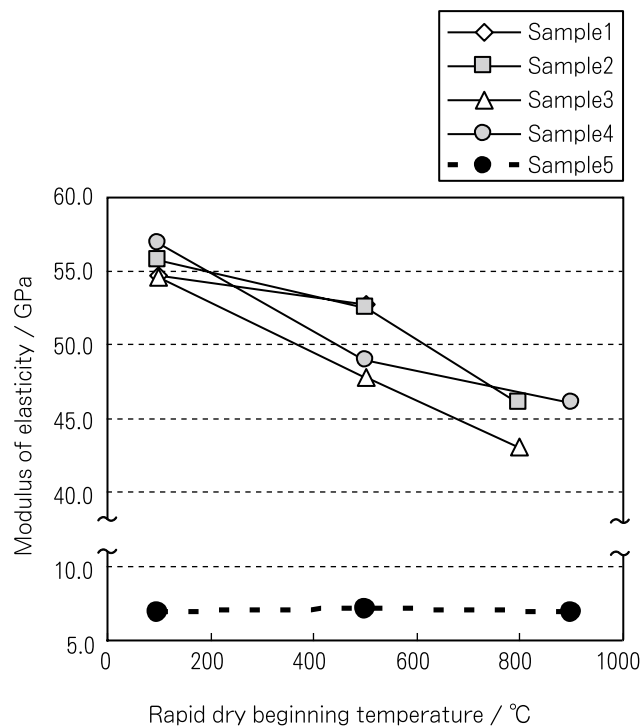


Fig. 8 Modulus of elasticity after 1000°C-3h heating with rapid drying.

爆裂限界温度が500℃以上の配合2, 3, 4, 5でさらに高い温度での急乾燥を行ったところ、セメントが5 mass%の配合2と汎用キャストブルの配合5には曲げ強さの低下は見られないが、取鍋材質のセメント7 mass%, 9 mass%の配合3, 4ではさらなる強度の低下が見られた。

②圧縮強度

500℃急乾燥の影響によりセメント7 mass%の取鍋材質配合に比較的大きな圧縮強度の低下が見られ、その他の取鍋材質配合に若干の強度低下傾向が見られた。

爆裂限界温度-100℃の急乾燥の影響により、セメント5 mass%, 9 mass%の取鍋材質配合2, 4にさらなる強度低下が見られた。汎用材配合5への影響は見られなかった。

③見掛気孔率

500℃急乾燥の影響によりセメント3 mass%の取鍋材質配合1に見掛気孔率の低下が見られた。

急乾燥の影響により取鍋材質配合2, 3, 4には若干の見掛気孔率の増加傾向が見られた。

汎用材配合5では500℃急乾燥の影響は見られなかったが、900℃急乾燥では見掛気孔率が若干低下した。

④嵩比重

いずれのサンプルも急乾燥による嵩比重への大きな影響は見られなかった。

⑤弾性率

500℃急乾燥の影響により低セメントキャストブルである取鍋材質配合に弾性率の低下が見られた。特にセメント量の多い配合3, 4に比較的大きな低下傾向が見られた。

爆裂限界温度-100℃のさらなる急乾燥では取鍋材質配合にさらに大きな弾性率の低下傾向が見られた。

配合5にはこのような急乾燥の影響による弾性率の低下傾向は見られなかった。

3. 3 回転るつば侵食試験結果

急乾燥が耐食性に及ぼす影響を調査した。

in apparent porosity was seen in ladle castables 2, 3, and 4. A decrease in the apparent porosity of utility sample 5 was seen with rapid drying at 900℃, even though no effect was seen when rapidly dried at 500℃.

④ Bulk density

No rapid drying influence on bulk density was seen in any sample.

⑤ Modulus of elasticity

By rapidly drying at 500℃, a decrease in the modulus of elasticity was seen in the ladle castables.

In specific, a comparatively big decrease was seen in samples 3 and 4.

By rapidly drying at 100℃ below explosive spalling temperature limit. Greater decrease in the modulus of elasticity was seen in the ladle castable samples.

3. 3 Results of corrosion test

The influence that rapid drying exerted on corrosion resistance was investigated.

Three samples were made under conditions a, b and c. The one sample was made by rapid drying at 300℃. And these samples were used for the corrosion test. Figs. 9 and 10 show the results of the corrosion test.

No large difference in the condition of the samples was seen.

4 Consideration

When ladle castables were rapidly dried, deteriorative tendency for the M.O.R, crushing strength, and modulus of elasticity were seen. Deterioration of these properties in the ladle castable was thought to be caused by the influence of internal vapor pressure during drying and the Influence of heat spalling during heating. But both influences were indistinct in this examination.

	Drying at 105°C-24h (Condition-a)	Rapid drying at 300°C	Rapid drying at 500°C (Condition-b)	Rapid drying at 800°C (Condition-c)
Cross section of samples				
Corrosion depth/mm	7.4	7.4	7.4	7.9

Fig. 9 Results of corrosion test.

配合 3 を用いて条件 a, b, c で作成したサンプル及び300℃急乾燥で作成したサンプルを用いた。試験結果をFig. 9, Fig. 10に示す。

条件 a のサンプルと比較して各条件とも大きな差が見られなかった。

4. 考察

実験結果より, アルミナ・マグネシア質キャストブルでは急乾燥による曲げ強さ, 圧縮強さ, 弾性率の低減が見られた。これらの要因として脱水時の内部蒸気圧の影響以外にも, 加熱時の熱スポーリングによる組織の劣化が考えられるが今回の試験ではそれぞれの影響が不明瞭である。これらを確認するため考察実験を行った。

内部蒸気圧の影響として, 自由水の影響と結晶水の影響が考えられるため, 自由水を脱水した状態のサンプルを作成した。また加熱時のスポーリングの影響を調べるため自由水, 結晶水ともに脱水したサンプルを作成した。

以下の条件でサンプルを作成し, 急加熱を行いこれらの影響を調査した。なお, 試験には配合 3 を用いた。

(1) 35℃ - 24h養生後105℃ - 24h乾燥したサンプル

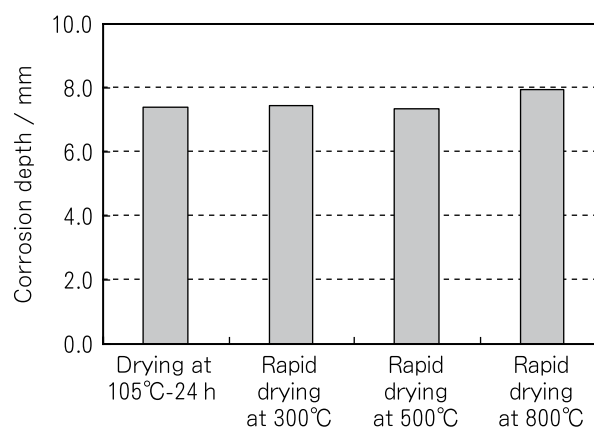


Fig. 10 Results of corrosion test.

To confirm these results, a further experiment was carried out.

Free water and crystallization water influence internal vapor pressure. The sample in the state to dehydrate free water was made. And to study the influence of heat spalling, a sample in the state of dehydrated free water and crystallized water was made. The following conditions were used to study the influence of rapid drying on castable properties. Sample 3 was used for this test.

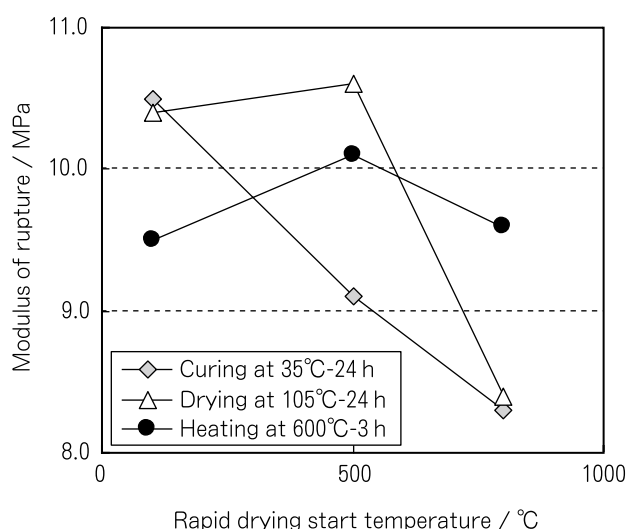


Fig. 11 Modulus of rupture after 1000°C-3h heating with rapid drying.

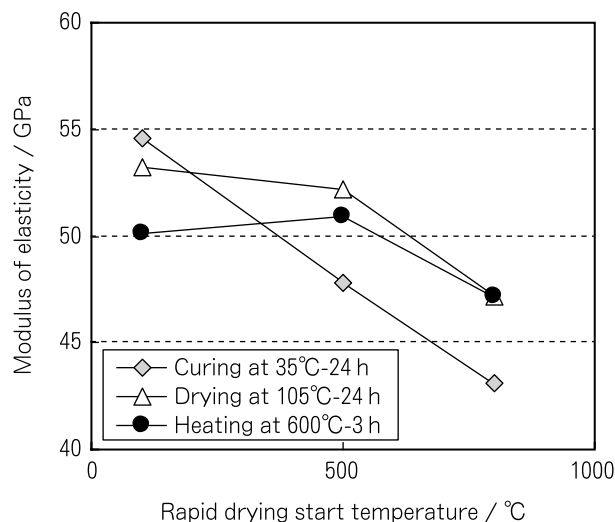


Fig. 12 Modulus of elasticity after 1000°C-3h heating with rapid drying.

ル（自由水を蒸発させた状態）。

- (2) 35°C - 24h養生後105°C - 24h乾燥し、600°C - 3h加熱したサンプル（自由水、結晶水ともに蒸発させた状態）。

サンプルの電気炉への投入温度は常温～（条件a相当）、500°C～（条件b相当）、800°C～（条件c相当）とし、各サンプルともに1000°C - 3h加熱を行った。

Fig. 11に曲げ強さ、Fig. 12に弾性率を示す。

養生後サンプルを用いて急乾燥試験を行うと、急乾燥開始温度に関して、曲げ強さ、弾性率ともに低減傾向が見られる。

一方、105°C - 24h乾燥後サンプルを用いて急乾燥試験を行うと、500°Cでは曲げ強さ、弾性率ともに大きな変化は見られないが、800°C急乾燥では曲げ強さ、弾性率ともに低減傾向がみられた。

このことから、500°C急乾燥における強度低下は自由水の蒸発による影響が大きいと考えられる。また、高い温度域（800°C）だと結晶水も急激に脱水されるため大きな強度低下が見られたと考えられる。

- 1) After curing at 35°C-24h (free water was evaporated).
- 2) After curing at 35°C-24h. Drying at 105°C-24h, and heated at 600°C-3h (free water and crystallization water were evaporated).

The sample was put into an electric furnace at a normal temperature, 500°C and 800°C, and then heated up to 1000°C, and heated at 1000°C-3h.

The results of the M.O.R measurements are shown in Fig. 11 and the Modulus of elasticity is shown in Fig. 12.

When the rapid drying tests were performed using the samples cured for 35°C-24h, decreases in M.O.R and modulus of elasticity were seen.

On the other hand, When the rapid drying test was performed using the samples dried at 100°C-24h, no decreases in M.O.R or modulus of elasticity were seen in the samples which were placed in a 500°C analectic furnace. But decreases in M.O.R and modulus of elasticity were seen in the samples put into an 800°C

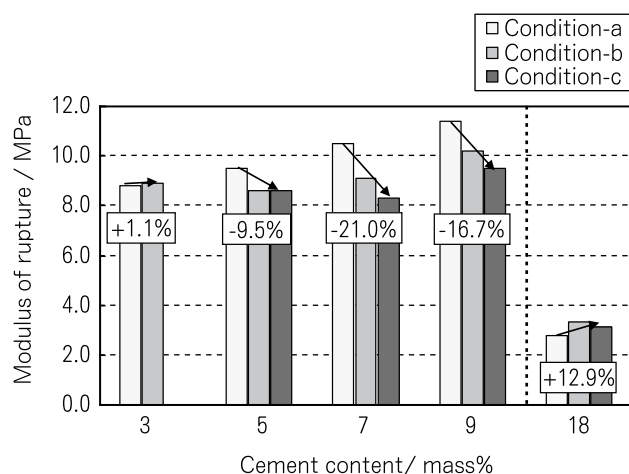


Fig. 13 Modulus of rupture after 1000°C-3h heating with rapid drying.

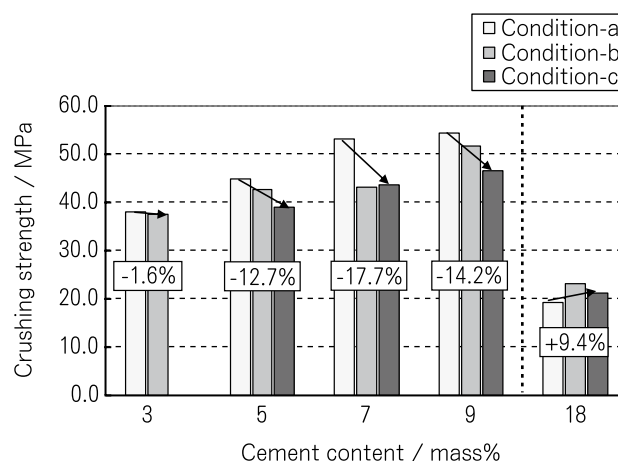


Fig. 14 Crushing strength after 1000°C-3h heating with rapid drying.

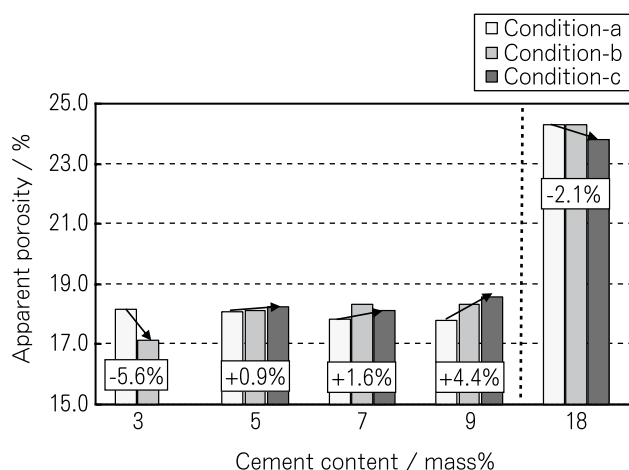


Fig. 15 Apparent porosity after 1000°C-3h heating with rapid drying.

105℃ - 24h乾燥後に600℃ - 3h加熱し、自由水と結晶水を事前に蒸発させたサンプルを用いて急乾燥実験を行うことで急加熱の際の熱スポーリングの影響を調べた。500℃では曲げ強さ、弾性率ともに大きな変化は見られない。800℃でも若干の弾性率の低下は見られるが、他の条件と比較するとその低下幅は減少している。

これらのことから、急加熱による熱スポーリングによる影響よりも、自由水、結晶水の脱水時の内部蒸気圧による影響の方が大きいと考えられる。

analectic furnace.

This results, suggests that the deterioration of ladle castable by rapid drying at 500℃ was caused by the influence of internal vapor pressure during drying. And the more severe lager deterioration of ladle castable by rapid drying at 800℃ is thought to have been caused by the influence of the dehydration of the crystallized water by rapid drying.

The rapid drying test was carried out using a sample which was cured at 35℃-24h and heated at 600℃-3h, and the Influence of heat spalling during heating was studied.

When rapidly dried at 500℃, no decrease in M.O.R or modulus of elasticity was seen in the samples. With rapid drying at 800℃, the decrease in modulus of elasticity was smaller than the sample made on the above-mentioned condition.

These results suggest that the influence of internal vapor pressure, when free water and crystallized water were dehydrated was larger than the influence of the heat spalling caused by the rapid heating.

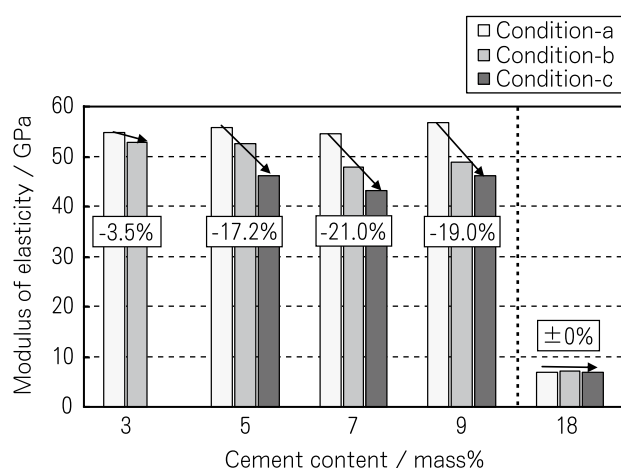


Fig. 16 Modulus of elasticity after 1000°C-3h heating with rapid drying.

乾燥条件 a, b, c における各特性値とセメント添加量との関係を以下の図に示す。Fig. 13に曲げ強さ, Fig. 14に圧縮強さ, Fig. 15に見掛け孔率, Fig. 16に弾性率をそれぞれ示す。図中に乾燥条件 a と c を比較した各特性値の変化の割合をあわせて標記した。

取鍋材質と汎用材質を比較すると、取鍋材質の方が急乾燥による特性低下が大きくなる傾向が見られた。取鍋材質は汎用材質よりも緻密な組織であるため、内部蒸気圧が高まりやすく、急乾燥によるダメージを受けやすいものと考えられる。

取鍋材質について、セメント添加量の少ないサンプルと多いサンプルを比較すると、セメント添加量が多い方が急乾燥時に特性低下が大きくなる傾向が見られた。セメント添加量の多いサンプルほど水和物の生成が多くなるため、結晶水の脱水時の内部蒸気圧の影響を受けやすいためと考えられる。ただし、セメント添加量の多い方が強度の低下率は大きいですが、絶対値は低セメントよりも高強度である。

5 結言

取鍋材質、汎用材質キャストブルについて耐爆裂性を調査し、その後、急乾燥が施工体の品質に

The following figure shows the relation between the cement content and rapid drying conditions a, b and c. The results of the M.O.R measurement are shown in Fig. 13. The crushing strength is shown in Fig. 14. The apparent porosity is shown in Fig. 15. Modulus of elasticity is shown in Fig. 16.

A ladle material and a utility material were compared. When rapidly dried, more deterioration of each property was seen in the ladle material.

The internal vapor pressure was thought to rise easily in the ladle material because the ladle material is denser than the utility material. Therefore, the ladle material was thought to be easily damaged by rapid drying.

Ladle material samples with little cement addition and samples with a large cement addition were compared. Rapid drying showed a larger deterioration tendency in the samples with a large cement addition.

There was a trend for the samples with larger cement contents to be more easily influenced by the internal vapor pressure when the crystallized water was dehydrated, because the amount of hydrate generation increased with a large cement addition in the samples. However the strength decreased more in the sample with a larger amount of cement content. But the absolute values were higher than the samples with low cement contents.

5 Conclusion

The explosive spalling resistance of ladle material and utility material was studied. After that we studied the influence of rapid drying on the properties of the castables. In the ladle material, the amount of cement content was changed, and the influence of the amount of

与える影響について調査した。なお、取鍋材質についてはセメント添加量を変化させ、セメント添加量と急乾燥が施工体の品質に与える影響について調査し、以下のことが明らかになった。

(1) 耐爆裂性

- ・セメント添加量が多いほど、養生強度が大きくなり高い耐爆裂性を示す。

(2) 急乾燥の影響

- ・取鍋材質はセメント添加量が多くなると、急乾燥によって強度が低下する傾向である。
- ・汎用キャストブルは急乾燥の影響による品質の低下は少ない。

(3) 急乾燥の耐スラグ性への影響

- ・大きな差は見られない。

cement content and rapid drying on the properties of the castables was studied. The following were clarified.

1) Explosive spalling resistance :

- ・Improvement in explosive spalling resistance was seen by increasing the cement content in the ladle material.

2) Influence of rapid drying :

- ・By rapid drying, there was a trend in the ladle materials for the samples with larger cement contents to be influenced more easily by the internal vapor pressure when the crystallized water was dehydrated.
- ・Rapid drying did not cause large deterioration in the utility materials.

3) Influence of rapid drying on slag resistance :

- ・No large difference was seen.

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