

プラスチック吹付け工法および材料の開発

Development of Plastic Gunning Installation Method and Materials

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Abstract

Plastic refractories are clay bonded materials in which fireclay is used as a plastic raw material, and are applied by ramming or by gunning with compressed air.

Our company has developed and markets plastic gunning materials and methods. Plastic gunning reduces the period required for refractory work in comparison with ramming, but its adhesion rate was inferior to dry and wet gunning, and it had the serious drawback that curing contraction after installation was larger than with ramming.

Therefore, various improvements were made in the equipment in order to improve the adhesion rate and workability, and materials with low curing contraction were developed. The results are described in this report.

1. はじめに

プラスチック吹付け工法は、可塑性のある耐火物を圧縮空気により吹付けて施工するものであり、ランマー施工に対して、材料を炉内に持ち込むことがなく、施工枠も必要がないうえ、工期短縮できる等の各種利点がある。当社は、1980年ごろより本施工方法および材料の開発および販売を進めてきたが、途中中断し、2005年にA社a製鉄所の混銑車吹付けで参入を果たした。また、本工法は加熱炉等の雰囲気炉でも使用される。

当社では本吹付け施工のことをSPG (Shinagawa Plastic Gunning) と称している。

プラスチック材料は骨材と水を加えると可塑性を示す粘土分を配合し、その材料に予め水や一部バインダーを加え粘性を出したものであり、炉の熱によって焼結することにより、煉瓦と同等になり、耐スポーリング性が非常に良好な耐火物といえる。このことから、加熱炉等のバーナ火炎の影響の強い工業炉や炉内温度変化の多いゴミ焼却炉にはプラスチック耐火物の使用が欠かせない。

1. Introduction

The plastic gunning is a method in which plastic refractories are installed by gunning with compressed air, and has various advantages in comparison with the ramming method, in that the material is not carried into the furnace, forms for placing the refractory are not necessary, the work period can be shortened, etc. Beginning around 1980, our company developed and marketed plastic gunning methods and materials, but later discontinued these activities. However, in 2005, the company participated in torpedo car gunning at a steel works of a certain steel maker. This method is also used with heating furnaces and other atmosphere-controlled furnaces.

At this company, this gunning method is termed SPG (Shinagawa Plastic Gunning).

An aggregate and a clay component which displays plasticity when water are added are

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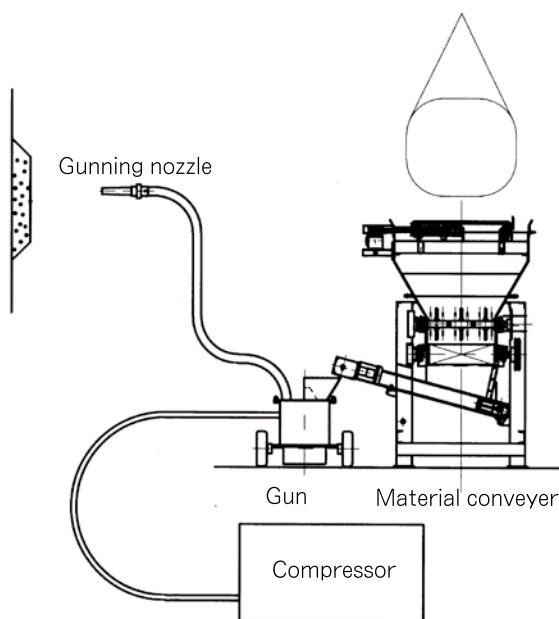


Fig. 1 Outline of plastic gunning equipment.

ただ、プラスチック材料はキャストブルのようにセメントや、特殊硬化剤を使用していないため、吹付けを行った場合、接着率は乾式や湿式吹付けに対し劣ることも知られている。また、施工後の養生後の線変化率は、プラスチック吹付け施工をランマーによる打ち込み施工と比較した場合、収縮が大きい欠点がある。

このことから現在までに接着率UP対策、現場作業性UP等の各種装置改善および、養生収縮の少ない材料の開発を行ったので報告する。

2. プラスチック吹付け工法の概要

Fig. 1 にプラスチック吹付けシステムの概要を示す。材料は500kgのワンウェイフレコンで納入される。フレコンをクレーンもしくはフォークリフトで吊り下げ、ホッパーに投入するが、その際フレコン底部を切り裂いて投入することになる。投入された材料は、ホッパー底部の切り出し装置により一定量排出され、ベルトコンベヤを介してガンに供給される。ガンからは圧縮エアとともにエア搬送され、ノズルより吐出し施工面に吹付けされる。

Table 1 に本装置の主仕様およびFig. 2 に装置概要の写真を示す。

本装置の吹付け吐出能力は2～5t/hであり、これを炉内3～4名、装置周辺3名程度で施工が行われる。通常加熱炉等で施工する場合は、上記メンバーで1日あたり15～18トンの吹き付けが可能

blended, and viscosity is obtained by adding water and part of the binder to this material in advance. When sintered by the heat of the furnace, the material becomes equivalent to brick, and can be considered a refractory material with extremely high spalling resistance. Based on this fact, the use of plastic refractories is indispensable in heating furnaces and other industrial furnaces in which the effect of the burner flame is strong, and in waste incinerators which are subject to numerous changes in the furnace temperature.

However, because plastic materials do not use cement or other special hardening materials like those used in castables, when only gunning is performed, it is known that the adhesion rate inferior to that in dry and wet gunning. Furthermore, the contraction after curing in plastic gunning is larger than that in rammer installation, which is a drawback of plastic gunning.

Based on these facts, to date, our company has made various improvements in the plastic gunning equipment, including measures to increase the adhesion rate and improve site workability, and has also developed materials with low curing contraction. The results are described in this report.

2. Outline of Plastic Gunning Method

Fig.1 shows an outline of the plastic gunning system. The material is delivered in 500kg one-way flexible containers. The flexible container is charged into a hopper by a crane or forklift, and in the process, the material is charged by cutting the bottom of the container. A set amount of the charged material is discharged by a cutout device at the bottom of the hopper, and the material is fed to the gun by way of a belt conveyor. The material is transported pneumatically from the gun together with compressed air, and is discharged from nozzle and gunned on the installation surface.

Table 1 shows the main specifications of the equipment. Fig.2 shows a photograph of the appearance of the equipment.

The gunning discharge capacity of this equipment is 2-5t/h. Gunning is performed with 3-4

Table 1 Specifications of plastic gunning equipment

Items	Specification
Material conveyer	Design : Shinagawa original Hopper capacity : Approx.1~2ton Cutout system : Kneading type Cutout capacity : 2~5ton/h Control : Inverter Feeding system : Belt conveyer
Gun	Design : Shinagawa original Wear plate : Deep bores (12) Revolution : 18~26rpm
Hose	Size : 50A Length : 20~60m
Nozzle	Design : Shinagawa original Material : Wear resistant rubber
Compressor (Rental in field)	Power : 135kW Air : 15m ³ /min~ Pressure : 0.69MPa

**Fig. 3 Appearance of fixed cutter for flexible container.**

となり、リバウンドロスの処理を考慮してもランマーによる打設に対し数倍の効率UPとなっている。また、天井等に施工する場合でもバック材にて炉壁を構築しておけば、特別な施工枠も必要がないため工事費は大きく軽減される。

3. 発生した問題点と改善項目

現在までにプラスチック吹付け施工を行ってきて発生したさまざまな問題点について、装置面・材料面両方から改善を行った。

1) フレコン開封装置の改善

当初フレコン下部を開封する方法として、ホッパー上部にFig.3に示すような固定式切れ歯を設けていた。しかし、この方法ではフレコン内部で

**Fig. 2 Appearance of plastic gunning equipment.**

personnel in the furnace and approximately 3 persons working around the equipment. When performing work in a heating furnace or similar facilities, the above-mentioned crew can spray 15-18 tons of material per day. Thus, even considering treatment of rebound loss, efficiency is increased by several times in comparison with installation with a rammer. Furthermore, when performing work on the furnace roof and similar parts, if the furnace wall is lined with back material, special forms are not necessary, and as a result, the cost of construction is greatly reduced.

3. Problems and Improvement Items

Improvement measures were implemented in both the hardware and material aspects in order to solve the various problems that had occurred when performing plastic gunning work up to the present.

1) Improvement of flexible container opening device

As the original method of opening the bottom of the flexible container, a fixed cutter, as shown in Fig.3, had been installed at the top of the hopper. However, with this method, the material inside the flexible container was compressed, making it difficult for the cutter to penetrate. Even when the container was lowered rapidly with a forklift, it is necessary to repeat this operation several times to take out the material from the container. In charging



Fig. 4 Appearance of mobile cutter for flexible container.

材料が圧着しており、歯が刺さりにくく、フォークリフトで素早く降下させた場合でも数回繰り返して材料を払い出せる状態となる。またクレーンで投入する場合は降下速度が遅いために、ほとんど開封できず、人が鎌等で追加切断せざるを得ないこともあった。よって、人が鎌で追加切断することは吊荷の下に手を入れることとなり、非常に危険な作業となっていた。

そこで、Fig.4に示すような移動式切れ歯を開発した。フレコンはフォークリフトまたはクレーンで一旦フレコン置き台の上に載せられ、モータ駆動により切れ歯が回転することによりフレコンが開封される。この装置により、開口半径も大きく取れることから、フレコンを吊り上げた時に内側に材料がほとんど残らず、スムーズな材料投入が可能となった。

これにより、開封に掛かるトータル時間の削減のみならず、人がフレコンに触ることもなくなり、安全性が非常に向上した。

2) 水添加装置

当社では一般品質であるPA-45Gが一般的に使用されているが、使用場所によってはハイアルミナ質となるPA-60G、PA-75Gといった材質を使用するケースも多い。アルミナ値が高くなるとその分粘土分が減少し可塑性が低くなる傾向となる。

そのため、このような材料は製造段階での水分添加調整が非常に困難であり、若干水分の多い状態では、ガンの入り口で詰まりが発生したり、ホッパー内部で付着が発生するなど、取り扱いが難しくなる。また、若干水分が少ない状態では施工時の接着率が悪くなり、非常に不経済となる。

with a crane, opening was virtually impossible due to the slow lowering speed, and additional manual cutting with a sickle or other tool was unavoidable. This additional manual cutting with a sickle was extremely dangerous work because it was necessary for the worker to place his hand under the hanging load.

Therefore, a mobile cutter was developed, as shown in Fig.4. The flexible container is placed once on the flexible container stand by the forklift or crane, and is opened by rotating the cutter by motor drive. Because this device has a large opening radius, virtually no material remains on the inside when the flexible container is hoisted, and as a result, smooth material charging has become possible.

This not only reduces the total time required for opening, but eliminates the need for personnel to touch the flexible container, thereby greatly improving safety.

2) Water addition equipment

Our company normally uses PA-45G, which is a general quality product as gunning material. However, depending on the use location, there are also many cases in which high alumina PA-60G and PA-75G materials are used. As the amount of alumina increases, the clay fraction decreases by a corresponding amount, and as a result, plasticity tends to decrease.

Therefore, adjustment of water addition in the manufacturing stage is extremely difficult with these materials. In a condition in which the water content is slightly high, handling becomes difficult. Typical problems include clogging of the gun inlet, adhesion of material inside the hopper, and the like. On the other hand, in a condition in which the water content is slightly low, the adhesion rate during installation is poor, and operation becomes extremely uneconomical.

Therefore, a simple water addition device was developed, as shown in Fig.5, and water is added in the gun. The structure of this device is extremely simple, in that the plastic water tanks are pressurized using the air supply part on the gun, and water is added by forcing out the water in the tank. As a guideline, the amount of



Fig. 5 Appearance of water addition equipment.

そこでFig.5に示すような簡単な水添加装置を開発し、ガン内部に水を添加するようにした。本装置の構造は非常に簡単なものとなっており、ガン手元のエア供給部よりポリタンクを加圧し、タンク内部の水を押し出す形で水を添加する。添加水量は材料吹付け量の約0.5%を目安としており、3t/hで施工する場合15ℓ/h程度である。これを目安に吹付け状態により増減できるようにニードルバルブを取付けている。

また、添加水は2個のポリタンクに分けて貯蔵しておくことにより、タンク切り替えにより連続して水添加できるようにしている。

本水添加方式を採用することにより、現場でのトラブルも皆無なうえ、接着率も70%以上を確保できるようになった。

3) リバウンド回収再添加装置

プラスチック吹付けは材料の特性上、湿式吹付けに対しリバウンド発生量が多く、納入材料増加、リバウンド材処理の問題等のデメリットがある。ただプラスチック吹付けの場合、リバウンド材をそのまま再度吹付けることが可能であることも知られている。

そこで、材料のロス低減と処理費用の低減および環境側面のニーズに対応すべく、簡単にリバウンド材を回収し、再度吹付け可能な装置の開発を行った。

本装置のシステム概要図をFig.6に、装置外観写真をFig.7に示す。

吹付け現場で発生したリバウンド材を切り出しエジェクタ装置に投入する。本切り出しエジェクタにて一定量の材料を、吹付け装置側のサイクロンまで空気搬送する。サイクロンでエア分離され

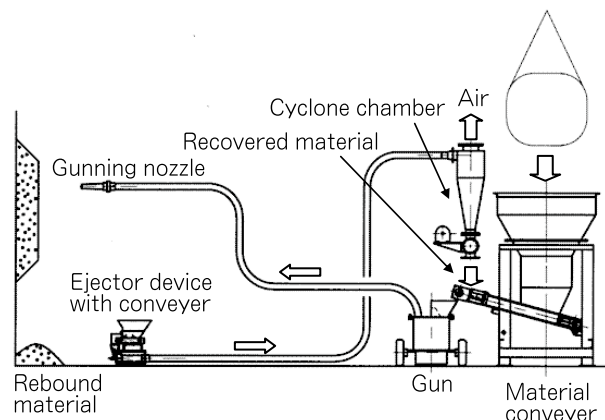


Fig. 6 Outline of rebound material recovery equipment.

water addition should be approximately 0.5% of the gunning material. Thus, if the gunning rate is 3t/h, the water addition rate will be approximately 15ℓ/h. A needle valve was installed to adjust the water addition rate to around this value as guideline corresponding to the gunning condition, with this as a guideline.

Furthermore, the added water is stored in two plastic tanks to enable continuous water addition by switching tanks.

Adoption of this water addition method has eliminated problems at the gunning site, and has made it possible to secure an adhesion rate of 70% or higher.

3) Rebound recovery and recycling equipment

Due to the characteristics of the materials used in plastic gunning, the amount of rebound material is large in comparison with wet gunning. This has the demerits of increasing the amount of material to be supplied, problems associated with treatment of the rebound material, etc. However, in the case of plastic gunning, it is also known that the rebound material can be gunned again in the as-recovered condition.

Therefore, equipment which enables simple recovery and regunning of rebound material was developed in order to reduce material loss, reduce treatment costs, and respond to environmental needs.

An outline of the equipment system is shown in Fig.6. A photograph of its external appearance is shown in Fig.7.

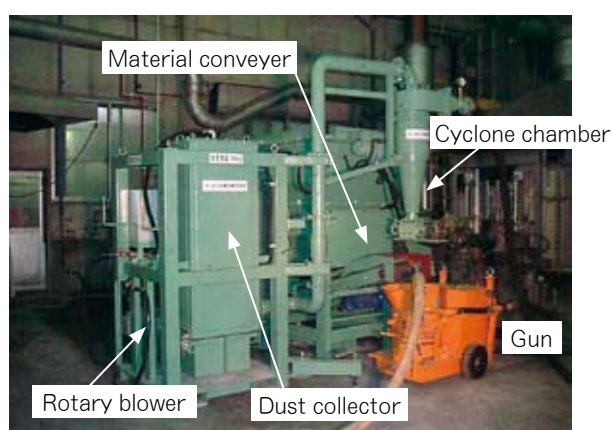


Fig. 7 Appearance of rebound material recovery equipment.

た材料はサイクロン下部のロータリーバルブを通過した後、直接ガンに再度投入される。

本装置の主仕様をTable 2 に示す。

本リバウンド回収装置の搬送能力は約700kg/h であるが、吹付機の通常吹付け量（約 3 t/h）に対し25%の添加量を確保できる。

本リバウンド装置を用いることにより、施工速度が2.8 t/h程度までならリバウンドのほぼ全量が

The rebound material generated at the gunning site is charged to the ejector device with conveyer. This ejector device with conveyer pneumatically transports the material at a set rate to a cyclone located beside the gunning equipment. After air separation by the cyclone, the material passes through the rotary valve at the bottom of the cyclone and is again charged directly to the gun.

The main specifications of this equipment are shown in Table 2.

The transport capacity of this rebound material recovery equipment is approximately 700kg/h. Thus, it is possible to secure an addition rate of 25% of the normal gunning rate (approx. 3t/h) of the gunning machine.

Using this rebound material recovery equipment, calculations show that it is possible to recover virtually 100% of the rebound material, assuming an installation rate of up to 2.8t/h. However, in actuality, there are many cases in which the spilled material cannot be recovered completely. As a result, the total adhesion rate is around 90%.

Table 2 Specifications of rebound material recovery equipment

Classification	Item	Specification
Material conveyer	Hopper content Cutout system Cutout capacity Feeding system Power	0.8m ³ Kneading type 1.0~3.3m ³ /h (1~3ton/h) Belt conveyer AC200V×7.5kW
Gun	Type Gunning capacity Utility air Power	Top-open type for SPG 1~5ton/h 10~15m ³ /min×0.2~0.3MPa AC200V×3.7kW
Material hose	Size	50A
Gunning nozzle	Type Size	Straight rubber nozzle φ 50mm×φ 30mm
Ejector device with conveyer	Feeding system Feed capacity Size Weight	Combination of ejector and belt conveyer with slide-up gate 700~1200kg/h 450L×380W×480H Approx.16kg
Recovery hose	Size	50A
Suction device	Separator Size Material outlet Dust collector Blower	Cyclone chamber φ 300mm×1050H Rotary valve (Shinagawa original) 0.2kW Bag filter type Rotary type 8m ³ /min×-29.4kPa×11kW

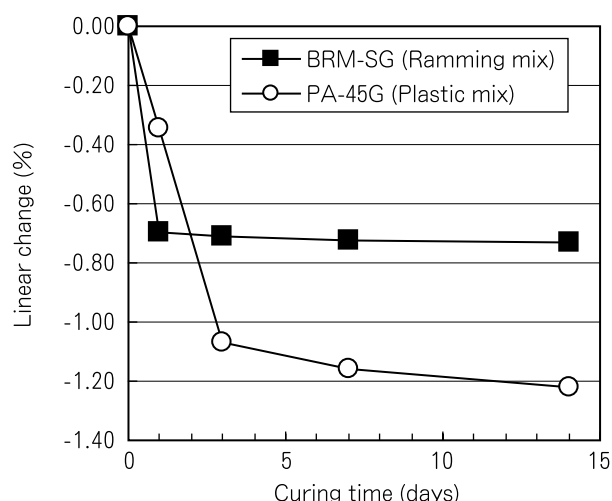


Fig. 8 Comparison of curing contraction.

回収可能になる計算ではあるが、実際にはこぼれた材料が回収しきれない場合が多く、総合的な接着率は90%前後となる。

4) 材質の改善

均熱炉・加熱炉に使用されるプラスチック吹付け材は、ラミング材に比較して施工効率は優位であるが、養生中に亀裂幅が大きくなる傾向が見られる。これは可塑性を向上させることで接着性を改善させるため、粘土や添加水分が多くなるためである。実際、プラスチック吹付け材PA-45Gとラミング材BRM-SGの40×40×160mm形状サンプルで養生中の線変化率を比較すると、PA-45Gは、施工後養生時の乾燥により材料が収縮し始め、2週間後には-1.22%まで収縮する。一方、ラミング材のBRM-SGをランマー打ち施工した場合の養生収縮率は2週間経過した時点で-0.73%にとどまっている (Fig.8)。

こうした収縮を抑制する施工方法としては、第一に養生時間の短縮があげられる。Fig.9に示すようにPA-45Gでも施工後1日後に乾燥した場合は、乾燥後の亀裂幅は小さく抑えられるが、養生時間が2週間と長い場合には、収縮率が大きくなり亀裂幅が広がる傾向が見られた。施工体からゆっくりと水分の蒸発が進む場合には、施工体の収縮は急乾燥よりも大きく現れることを示しており、施工後はできるだけ早期に乾燥に入ることが必要であることが分かる。一方、すぐに乾燥に入れない場合には水分の蒸発を抑制することが必要である。ビニールシートでの養生は水分蒸発を抑制し、養生収縮亀裂の抑制に効果がある。

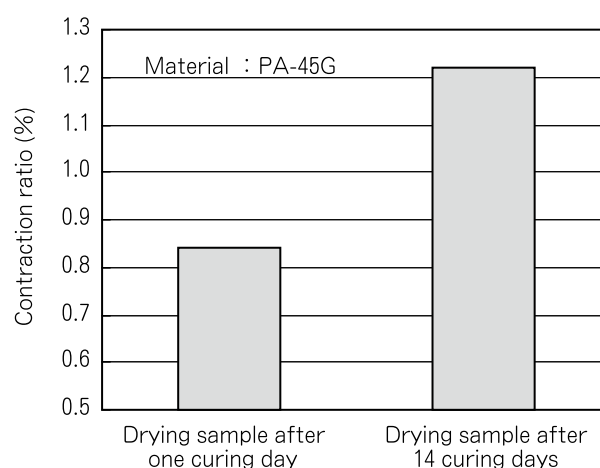


Fig. 9 Influence of curing time on contraction ratio.

4) Improvement of material

The plastic gunning materials used in soaking furnaces and heating furnaces have superior installation efficiency in comparison with ramming materials, but the increase in crack width during curing tends to be excessive. This is due to excess addition of clay and water in order to improve adhesion by increasing plasticity. The linear change rate during curing was compared with samples of the plastic gunning material PA-45G and the ramming material BRM-SG with dimensions of 40 × 40 × 160mm. The contraction of the PA-45G material due to drying began during curing after installation and reached -1.22% after 2 weeks. On the other hand, the curing contraction rate of the BRM-SG ramming material installed using a rammer was limited to -0.73% after 2 weeks (Fig.8).

In installation methods to suppress this contraction, shortening of the curing time is most important. As shown in Fig.9, when PA-45G was dried one day after installation, the width of the cracks after drying was held to a small size, but when the curing time was long, for 2 weeks, a tendency of increasing contraction rate and expanding crack width could be seen. This shows that contraction of the installed refractory is larger when evaporation of the water from the refractory proceeds slowly than with rapid drying, and it is necessary to begin drying as

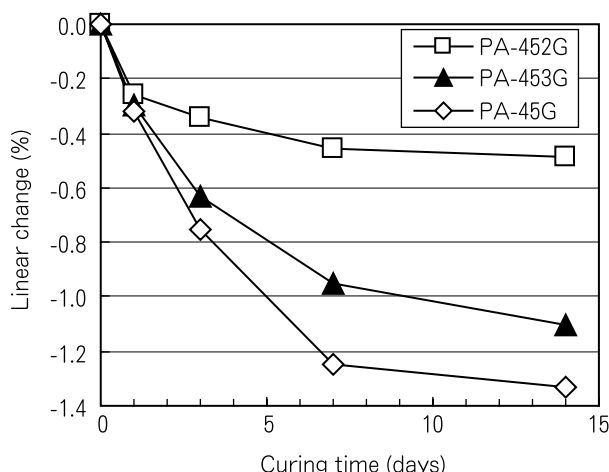


Fig.10 Contraction inhibiting effect of improved materials.

材料の養生収縮対策品としては、硬化を早めることで養生収縮を抑制した気硬性の材料 PA-453Gと、施工体の養生中の乾燥を阻害することで養生収縮を抑制している熱硬性の材料 PA-452Gを開発した。これら2材質と PA-45Gの吹付けテストを行い1000×500×250mmの施工体を作成し、その線変化率を測定した (Fig.10)。PA-45Gは、初期の収縮が大きく14日後には-1.33%まで収縮していた。これに対し気硬性のPA-453Gは14日後でも-1.10%にとどまり収縮抑制効果が確認できた。さらに乾燥抑制したPA-452Gは、大幅に収縮が小さくなり、14日後でも-0.49%に抑制され、BRM-SG (-0.73%) よりも養生収縮抑制することができた。

4. まとめ

上記のごとくプラスチック吹付け施工 (SPG) に関し、客先および施工業者の方々に満足頂けるよう各種改善を図ってきた。しかしリバウンド発生量のさらなる低下、リバウンド回収効率のさらなる改善等、課題は残っている。このような課題を早期に解決し、さらに使いやすく客先に喜んでいただけるSPGシステムを構築したい。

soon as possible after installation. On the other hand, in cases where it is not possible to begin drying immediately, it is necessary to suppress water evaporation. Curing under a vinyl sheet suppresses water evaporation, and thus has the effect of suppressing curing contraction cracks.

As the gunning material which inhibits contraction, our company developed PA-453G, which is an air-hardening material that inhibits curing contraction by accelerating hardening, and PA-452G, which is heat-hardening material that inhibits curing contraction by retarding drying of the installed refractory during curing. A gunning test was performed with these two materials and the conventional material PA-45G. Specimens with dimensions of 1000 × 500 × 250mm were prepared, and their linear change was measured (Fig.10). PA-45G showed large contraction in the early period, and had contracted to -1.33% after 14 days. In contrast, contraction of the air-hardening material PA-453G was limited to -1.10% after 14 days, confirming the contraction inhibiting effect. With the drying-inhibiting material PA-452G, contraction was greatly reduced, being limited to -0.49% after 14 days. Thus, it was possible to reduce curing contraction even in comparison with BRM-SG (-0.73%).

4. Conclusion

As described in this report, various improvements were made in the plastic gunning method (Shinagawa Plastic Gunning: SPG) in order to improve the satisfaction of customers and installation contractors. However, some issues remain, including further reduction in the amount of rebound material and further improvement in rebound material recovery efficiency, etc. The authors intend to solve these problems at an early date and create a more easily used SPG system for improved customer satisfaction.