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Characteristics of Burst Pressure and Abrasion Resistance of Concrete Hose with Aramid Fiber Reinforcement and Rubber Composition

Yong-Hwan Kim[*,**], Seung-Hwan Lee[*], Il-Kyung Sung[*], Yu-wool Lee[**], Myungchang Kang[**,#]
[*]HWASEUNG EXWILL Co.,Ltd., 1079, Jungang-daero, Yeonje-gu, Busan, 47540, Korea
[**]Graduate school of convergence science, Pusan National University, Busan, 46241, Korea

아라미드 섬유강화 및 고무조성에 따른 콘크리트 도킹호스의 파열압력과 내마모도 특성

김용환[*,**], 이승환[*], 성일경[*], 이여울[**], 강명창[**,#]
[*](주)화승엑스윌, [**]부산대학교 융합학부

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ABSTRACT

A concrete docking hose of pump car's boom pipe line have been used in many construction sites. They are long structures with continuous cornering, similar to a trunk of the elephant, characterized by a very high pressure resistance of 20MPa. They need flexible materials and structure in order to move the hose smoothy. But commercial concrete hose is hard to handle and heavy owing to adaption of steel reinforcement. In this study, it is tried an experimental approach to the characteristic of inner rubber layer and abrasion resistance. Also, we are investigated the bursting pressure according to the reinforcement of the hose and propose the usefulness of the hose reinforced with high strengthened aramid fiber.

Key Words : Concrete Docking Hose(콘크리트 도킹호스), Aramid Fiber Reinforcement(아라미드 섬유 강화재), Abrasion Resistance(내마모성), High Pressure(고압력)

1. Introduction

In recent years, the demand for high-performance equipment in the building sector has increased due to the increase in the number of large and ultra-high buildings. In particular, a concrete docking hose (hereafter referred to as a hose) plays a role in transferring liquid concrete by high pressure[1].

Corresponding Author : kangmc@pusan.ac.kr
Tel: +82-51-510-2361, Fax: +82-51-581-7396

Toyo Tire & Rubber Co., Ltd. and Ohji Rubber & Chemicals Co., Ltd.[2-4] formed a hose using steel cord and steel wire as reinforcement. Park et al.[5] reported the fatigue strength and glass fiber content of the insulation system in a liquefied natural gas carrier (LNGC). Han et al.[6-7] conducted a study on the molding properties of carbon fiber-reinforced composites. Ganjali et al.[8] identified the correlation between the contents and characteristics of poly-butadiene in natural rubber butadiene (RB) materials. Jang and Shin[9-10] studied the compositions and characteristics of RB and natural rubber (NR) and hose thickness and damage. They found that if existing hoses whose reinforcement is steel wire or steel cord are deformed, they are not restored, and they lose their functions.

Thus, this study aims to analyze the hoses manufactured by A Company (hereafter referred to as T-1) and B Company in the USA (hereafter referred to as T-2) in terms of steel reinforcement, which have been widely used in construction sites in Korea, and an aramid fiber-reinforced hose (hereafter referred to as T-3) in terms of rubber composition. It also investigates the basic rubber and additive types in the inner rubber layer and changes in abrasion resistance according to the contents using the experimental approach. Finally, it aims to investigate the rupture pressure and its characteristics according to each layer structure in the hose, such as the type of reinforcement that determines the hose's capacity to resist pressure, thereby proposing the usability of the aramid fiber-reinforced concrete docking hose.

2. Design and evaluation method of aramid fiber-reinforced concrete docking hose

2.1 Design of composition of hose's inner rubber layer

Fig. 1(a) shows the pump truck that transfers the liquid concrete to the preferred location through the boom pipeline and the concrete docking hose. Fig. 1(b) shows the cross-section of the hose whose inner diameter is 5 inches. The hose is structured with three layers: an inner rubber layer on the inside, a reinforcement layer between the inner and outer rubber layers of the hose, and an outer rubber layer on the external side of the hose. Table 1 presents the major components of the inner rubber layers of the T-1 and T-2 hoses and their

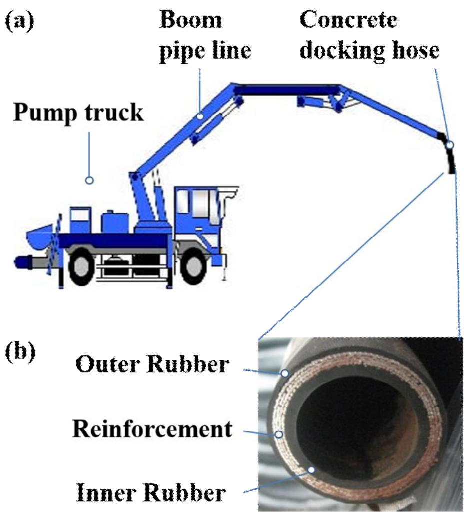


Fig. 1 Schematics of (a) pump truck and concrete docking hose and (b) structure of hose

characteristics. The major rubber components of T-1 were 52wt% mixed NR and BR and 31wt% carbon black. T-2 was composed of 60wt% mixed NR and BR and 28wt% carbon black. The abrasion resistances of the two hoses were 101 mm^3 and 100 mm^3, and the burst pressures were 19.9 MPa and 20.2 MPa, respectively.

With the mix design of the inner rubber layer in the hose, NR and BR, whose abrasion resistance is excellent, are mixed, and carbon black is added to test the physical properties[11-13]. The quantiles of four ingredients—NR, BR, intermediate super abrasion furnace (ISAF) carbon black, and high abrasion furnace (HAF) carbon black—were changed. The parts per hundred rubber (PHR), which is the mix unit, refers to parts per 100 by weight of the mixed NR and BR. Table 2 shows the mix table.

2.2 Optimal design of aramid fiber-reinforced hose

For the reinforcement of the hose, Heracron HF220 (Kolon Industry Co., Ltd.), a high-strength aramid fiber, was selected[14]. The characteristics of the aramid fiber are presented in Table 3. The breaking force of the aramid fiber was 338 N, and the elongation was 3.3%. Thus, Young's modulus and elongation were low, which means it had high strength characteristics. Table 4 presents the design table of aramid fiber reinforcement-applied T-3. In the design, the working pressure (WP) of the hose was 10 MPa, the design burst pressure (DBP) was 20 MPa, and 8-ply reinforcement was used in consideration of the breaking force.

2.3 Rubber composition and method to assess burst pressure

For the assessment of rubber composition, the tensile, elongation, hardness, aging, and adhesive strength tests were conducted in accordance with the physical test methods for vulcanized rubber in Korean Industrial Standards (KS) M 6518[15]. For the assessment of rubber composition, the tensile, elongation, hardness, aging, and adhesive strength tests were conducted in accordance with the physical test methods for vulcanized rubber in Korean Industrial Standards (KS) M 6518[15]. For the abrasion resistance, tests were conducted according to the rubber, vulcanized or thermoplastic determination of abrasion resistance using a rotating cylindrical drum device in KS M ISO 4649:2012[16]. In addition, the burst pressure of the hose was tested in accordance with the rubber and plastics hoses and hose assemblies hydrostatic testing in KS M ISO 1402:2012[17].

3. Experiment results and discussion

3.1 Fabrication of aramid fiber-reinforced hose

The rubbers were fabricated and experimented according to the four mixes in Table 2 to investigate the physical properties and abrasion resistances of the rubbers. The results obtained that HI-1, HI-2, HI-3, and HI-4 of each compounds formation had abrasion resistances of 103 mm^3, 98 mm^3, 79 mm^3, and 60 mm^3, respectively. Thus, HI-4 showed the best performance.

Table 5 presents the assessment results of the major physical properties, such as hardness, tensile strength, elongation, abrasion resistance, and adhesive strength, of the internal rubber layer. Fig. 2 shows the comparison graph of abrasion resistances. The hose was fabricated by the spiral winding method using the hose forming machine in mandrel mode shown in Fig. 3.

3.2 Characteristics of burst pressure of concrete docking hose

Fig. 4(a) shows the burst test device of the hose. Water pressure was applied until the hose burst after the water pressure hose was connected. Figs. 4(b) and 4(c) show the photos of the burst hoses. Fig. 5 shows the burst pressure test results, in which T-1 burst at 19.9 MPa in 12 min and 21 sec, T-2 burst at 20.2 MPa in 11 min and 51 sec, and T-3 burst at 22.1 MPa in 13 min. Fig. 6 shows the bending radius results of the hoses, in which T-1 and T-2 were 550 mm, and T-3 was 350 mm.

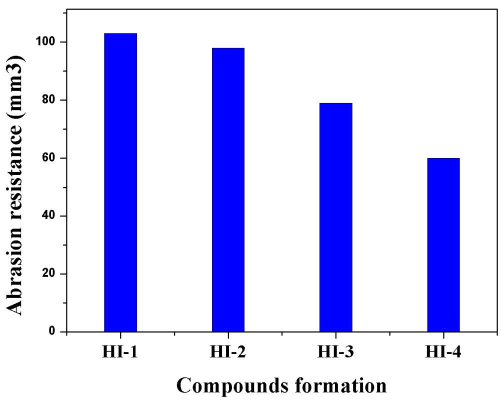
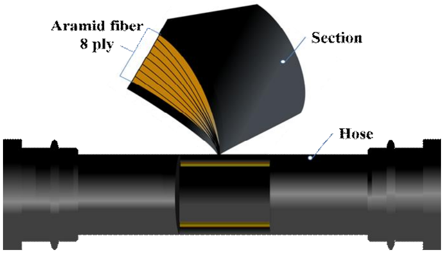


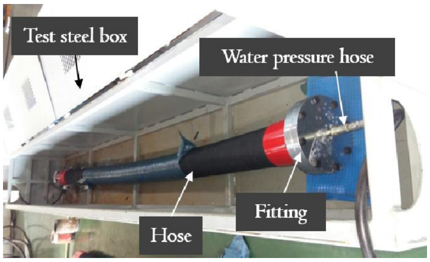
Fig. 2 Comparisons of abrasion resistance for inner rubber

(a) Mandrel of 60m length

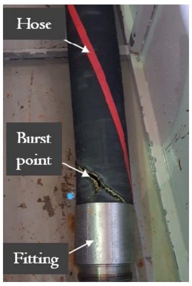


(b) Schematics of 8ply aramid fiber hose

Fig. 3 Mandrel process and hose structure manufactured by armid fiber



(a) Internal configuration diagram of burst pressure test for hose



(b) T-1 at 19.9MPa (c) T-3 at 22.1MPa

Fig. 4 Burst pressure measuring method input by the water inside the hose

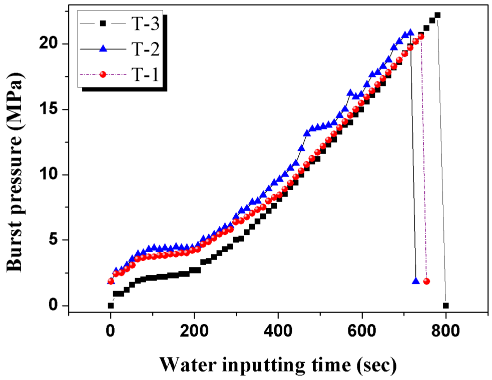


Fig. 5 Comparisons of burst pressure for existing T-1, T-2, and T-3 aramid fiber reinforced concrete docking hose

(a) T-1, T-2 hose (b) T-3 hose

Fig. 6 Comparisons of bending radius of T-1, T-2 550㎜ and T-3 350㎜

4. Conclusions

This study fabricated a concrete docking hose considering the aramid fiber reinforcement and abrasion resistance and investigated the relationship between the hose's abrasion resistance and burst pressure. The following conclusions were drawn:

1. The T-3 hose's internal rubber layer had an abrasion resistance of 60 mm^3 due to the content composition of BR 45phr, ISAF

40phr, and HAF 15phr, whose abrasion resistances were excellent among the rubber components, resulting in 40% better performance than T-1 and T-2.

2. The T-3 aramid fiber-reinforced concrete docking hose had a burst pressure of 22.1 MPa and exhibited 10% better performance than T-1 (19.9 MPa) and T-2 (20.2 MPa).
3. T-3 had a bending radius (displays the hose's flexibility) of 350 mm, making it 36% more flexible than T-1 and T-2. T-3 (38 kg) was 17% lighter than T-1 and T-2 (46 kg). The evaluation result showed that the fiber reinforcement was more flexible and lightweight than steel wire.

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