# Investigation of the changes in reflective properties of reflective tapes due to various effects

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**ABSTRACT – REZUMAT**

**Investigation of the changes in reflective properties of reflective tapes due to various effects**

*Mankind's need to protect itself from various dangers, cold, heat and other natural phenomena have survived from the first days of its existence to the present day. Materials with high visibility have also been developed primarily with the need for protection. These materials are widely used on bicycle wheels, road signs and traffic signs in daily life. Materials used in various textile products such as activewear, sportswear, children's clothing, accessories, hats, uniforms, foot and armbands, and backpacks make life easier by providing safety for the people who walk with their pets, as well as road workers, traffic policemen, firefighters, pedestrians and bicycle riders people who do sports and walking at night due to their busy life.*

*Many of the traffic accidents occurring today are due to the inability to notice individuals moving on the side of the road. In conditions where the lighting is not sufficient, the reflective feature of the clothes worn will allow people to be noticed more easily. Reflective tapes are used to add reflective properties to clothes. However, these tapes may lose their reflective properties as a result of the various effects they are exposed to. A performance loss that may occur in reflective tape properties due to these effects will put the wearer's life at risk. For this reason, in this study, the changes in the reflective properties of retroreflective tapes after various effects were investigated.*

***Keywords:*** *retroreflectivity, reflective tapes, safety clothing, high visibility, knitted fabric, woven fabric*

**Investigarea modificărilor proprietăților reflectorizante ale benzilor reflectorizante din cauza diferitelor efecte ale acestora**

*Nevoia omenirii de a se proteja de diverse pericole, frig, căldură și alte fenomene naturale a supraviețuit din primele zile ale existenței sale până în zilele noastre. Materialele cu vizibilitate ridicată au fost, de asemenea, dezvoltate în primul rând din necesitatea de protecție. Aceste materiale sunt utilizate pe scară largă în viața de zi cu zi pe roțile de biciclete, semnele rutiere și semnele de circulație. Materialele utilizate în diverse produse textile precum îmbrăcămintea activă, îmbrăcămintea sport, îmbrăcămintea pentru copii, accesoriile, pălăriile, uniformele, benzile pentru picioare și brațe, rucsacurile, ușurează viața, oferind siguranță persoanelor care se plimbă cu animalele de companie, precum și lucrătorilor rutieri, polițiștilor rutieri, pompierilor, pietonilor și bicicliștilor, persoanelor care fac sport și se plimbă noaptea din cauza vieții aglomerate.*

*Multe dintre accidentele de circulație care au loc astăzi sunt cauzate de incapacitatea de a observa persoanele care se deplasează pe marginea drumului. În conditiile în care iluminarea nu este suficientă, caracteristica reflectorizantă a articolelor purtate va permite persoanalor să fie mai ușor observate. Benzile reflectorizante sunt folosite pentru a adăuga proprietăți reflectorizante articolelor de îmbrăcăminte. Totuși, aceste benzi își pot pierde proprietățile reflectorizante ca urmare a diferitelor efecte la care sunt expuse. O pierdere de performanță care poate apărea în proprietățile benzii reflectorizante din cauza acestor efecte va pune viața purtătorului în pericol. Din acest motiv, în acest studiu au fost investigate modificările proprietăților reflectorizante ale benzilor retroreflectorizante după diferite tratamente.*

***Cuvinte-cheie****: retroreflectivitate, benzi reflectorizante, îmbrăcăminte de siguranță, vizibilitate ridicată, tricot, țesătură*

## INTRODUCTION

The need of human beings to protect themselves from various dangers, cold, heat and other natural events has remained up-to-date since the first days of its existence. High-visibility materials were also developed primarily out of the need for protection.

Most of the traffic accidents occurring today are due to the low visibility of individuals moving on the roadside [1]. The human eye perceives large and contrasting objects and objects with brightness and mobility more easily. Therefore, high-visibility clothing helps drivers see individuals moving along the road earlier. While reflective clothing protects the wearer from risks, they do not eliminate the risk but will optimize visibility and significantly reduce the risk of accidents [1]. The safety of people who are at risk of being hit by vehicles can be increased by the use of high-visibility clothing with appropriate features and designs.

According to the statement made by the General Directorate of Security Traffic Services Presidency on life safety in traffic, it was stated that in the accidents that occurred in 2014, 22.7% of the pedestrians were involved in an accident at night and the most

important reason for these accidents was that the pedestrians were not noticed by the drivers. In this context, it was stated that it would be beneficial for traffic safety to use reflective clothing and accessories (such as bags, and hats) that will increase the visibility of pedestrians and especially child pedestrians at night and make them easier to be noticed by drivers [2].

When the statistical data are examined, it has been recorded that 413 pedestrians lost their lives in the accident and 10,620 people were injured during the dark hours of the day between 2011 and 2013 in Turkey. As can be seen from these data, hundreds of people lose their lives and thousands are injured by the effect of not being visible enough in dark environments [3].

The best solution to prevent accidents is to make the pedestrian as visible as possible. This goal can be achieved if pedestrians wear clothing made of retroreflective materials [4].

High-visibility garments are generally used in hazardous work environments with poor light, bad weather or heavy traffic to increase visibility and ensure user safety [5].

In this study, the reflective tapes and the changes in the reflection properties of the tapes after various effects were investigated.

## Usage areas of high-visibility clothing

High visibility in workwear is very important. Work clothes are clothes worn to prevent the risk of exposure to harmful substances and bad environmental conditions, to protect them from this risk and/or to reduce this risk [6]. These garments are within the scope of protective clothing and they are used by various professional groups such as road workers, traffic police, firefighters, pedestrians and cyclists, warehouse operators, park operators, forestry workers, railroad workers, emergency response personnel, law enforcement officers, parking attendants, road construction workers and roadside assistance personnel.

Today, due to the workload, many people have the opportunity to do sports in the evenings. High visibility is even more important in the dark, in heavy traffic or bad weather conditions. Today, there are many reflective clothing and accessories (bags, hats, wristbands, belts, etc.) produced in this field. In addition, high-visibility clothing is used in athletes' clothing and shoes, children's clothing, pedestrian clothing, hats, gloves or backpacks, and pet clothing because working people walk their pets in the evening [7].

It is thought that high-visibility clothing helps to be aware of children who are in traffic and use their bicycles to go to school. Today, there are many accessories with this feature such as wristbands, umbrellas, belts, gloves, covers for bicycle saddles, shoes, etc.

## Methods of giving high visibility to clothing

High-visibility clothing can be a textile product in the form of vests, trousers or overalls. High-visibility clothing optimizes visibility in low-light and dark environments, especially in autumn and winter.

High visibility feature can be given to textile products in 3 ways:

- Reflective materials: this glow when exposed to light.
- Fluorescent materials: it appears as a red-orange colour all day long.
- Photoluminescent materials: these materials store energy by absorbing daylight or artificial light and give a green-yellow colour in the dark [8].

Fluorescent material takes some of the invisible ultraviolet light from sunlight and sends it back to the viewer as more visible light, thanks to special pigments. Reflective and fluorescent materials emit light when exposed to light emitted from any external source [9]. The reflective (reflective) material in the high-visibility clothing makes it easier for pedestrians to be detected by oncoming vehicle drivers, especially when pedestrians are on the move [10].

Photoluminescent materials, such as textile dyes and printing dyes, can be applied to textile products in the form of fibre, yarn and fabric with techniques such as dye printing, coating and lamination. However, the application of photoluminescent materials to any textile surface with these methods increases the hardness of the product and especially affects the comfort of clothing [9]

## Features of reflective (retroreflective) tapes

Retroreflective material reflects light in the direction of the light source, for example, making pedestrian visibility brighter and more visible at night than non-reflective materials [11].

Reflective tapes usually consist of small glass beads or prismatic elements encased in a transparent film. The most commonly used type is tapes created by bead technology. Microscopic glass beads of different diameters are dispersed over the surface of a substrate layer, usually a textile material. These beads adhere to the substrate with an adhesive layer. The performance of the tape is determined by several factors; Bead sizes, how spherical the beads are, the distribution of the beads on the surface, and the depth at which they are embedded in the adhesive layer are all factors that affect tape performance. The durability of a tape depends not only on how well the individual beads are held on the tape but also on the flexibility of the adhesive layer and the strength of the substrate material [12].

Another type of retroreflective (reflective) tape often used in high-visibility personal protective equipment consists of micro prismatic structures. This type of material is embossed with many reflectors shaped like cube corners. These can be arranged in different directions to provide different retroreflective properties. Each micro prismatic shape works by reflecting light from three sides of its structure.

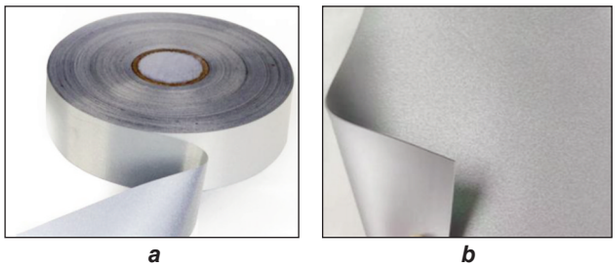
## Use of reflective (retroreflective) tape in clothing

Reflective tapes are used to increase the wearer's visibility to others, especially in the dark, and are

often sewn or affixed. The tape alerts other people of the person's presence by reflecting light. The tape is generally applied on work clothes, overalls, vests and jackets in various ways, such as vertical, horizontal or cross (X) [13].
The properties of high-visibility clothing and reflective materials were investigated by various researchers.
In their study, Uonarosa and Ayer conducted a daytime field study to investigate the effects of clothing colour, amount of reflective material, driver age and season on the perceived distance of pedestrians by drivers, and the distances at which pedestrians were first detected were recorded. The results showed that the amount of reflective material and the season significantly affect the distance at which pedestrians are perceived by drivers [14].
In this study, Sayer and Mefford conducted a natural field survey to evaluate the effects of clothing colour, amount of reflective material, pedestrian arm movement, traffic density and driver age on the daytime appearance of personal safety clothing. The study showed that high-visibility clothing features increase pedestrian visibility in both day and night conditions [15].
Costello and Wogalter, measured whether people were willing to pay more for clothing with reflective materials compared to clothing without reflective materials, and concluded that they were willing to pay more for reflective materials in clothing [6].
Wood et al. determined the drivers' ability to detect pedestrians at night in their study. Results show that driver age, clothing form, headlights and glare significantly affect performance [5].
Fekety et al. investigated the visibility benefits of adding electroluminescent (EL) panels to pedestrian clothing containing retroreflective materials. Studies have shown that pedestrians are not visible enough to drivers at night and that retroreflective materials can increase pedestrian visibility [16].
Akgün et al. stated in their study that the colour perception of the fabric affects the colour and reflectance (reflection) properties of the yarns in the fabric structure [17].
In conditions where the lighting is not sufficient, especially the insufficient retroreflective properties of the workwear puts the employee's life in danger. It is desired that the visibility features of workwear are sufficient to meet the expectations not only when they are used for the first time, but also after washing and long periods of use. A performance loss that may occur in the properties of reflective tapes due to use and mechanical effects may endanger the life of the wearer [18].
This study was conducted to reveal the changes in the reflection properties of reflective tapes under different conditions.

## MATERIAL AND METHODS

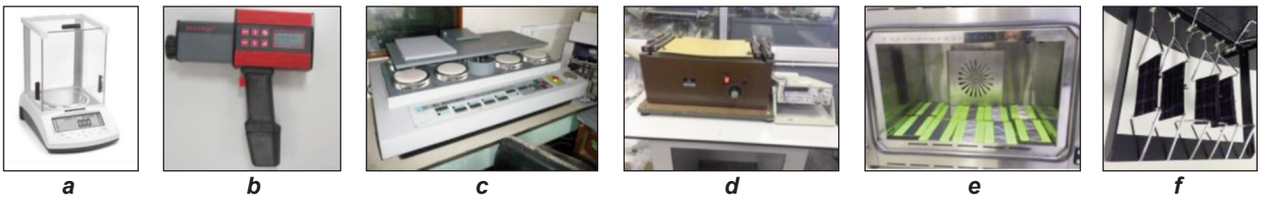
In the research, 100% polyester, neon yellow coloured, interlock knitted fabric and woven fabric, which are two types of fabrics that are widely used in the production of high-visibility clothing, were used. As a reflective tape, 2 different types of reflective tapes were used, one of which is stitched to the fabric and the other is adhered to the fabric (figure 1).



*a* *b*

Fig. 1. The reflective tape joined by:
*a* – stitching; *b* – self-adhesive reflective tape

The tape to be joined by stitching was sewn with 100% polyester sewing thread with 4 stitches per cm. The self-adhesive reflective tape was adhered to the fabric in an industrial iron under operating conditions and the film layer on it was removed after cooling.
To investigate the reflective performance of the fabrics, first of all, the reflection values of the bands were measured. Then, tests such as abrasion, stretching, washing, and UV ageing were applied to the tapes in their current state and when they were sewn or adhered to fabrics, and then the change in the reflection performance of the tapes was evaluated.
All materials were conditioned for 24 hours at 20°C±2 temperature and 65±5% relative humidity under standard atmospheric conditions before the test.
Weight: It is the weight in grams of one square meter of fabric. The fabrics' weight was made with five test samples according to the TS 251 standard. The fabrics were cut with a 100 $cm^2$ weight template and weighed on a precision scale (figure 2, *a*).
Retroreflective performance determination: Measurement of the retroreflective performance of the reflective tapes used, individually and sewn or glued to the fabric, was made with the retroreflectometer in



*a* *b* *c* *d* *e* *f*

Fig. 2. Images of: *a* – precision scale; *b* – delta retrosign retroreflectometre; *c* – Martindale abrasion tester (James Heal); *d* – flexing tester; *e* – UV ageing test chamber; *f* – knitted fabric stretch recovery tester

figure 2, *b*. In the measurement, retroreflectivity coefficient "R", 90° rotation angle, 12' observation angle and 5° entry angle were used.
While measuring, the device is placed on the retroreflective marking surface so that only the desired region is in the measuring area of the device. After the first measurement was taken, the retroreflectometer was shifted to other parts of the reflective fabric and measurements were continued.

***Abrasion***

Abrasion is the deformation that occurs as a result of any material rubbing against another surface. This test was carried out to check whether the reflection properties of the tapes have changed in high-visibility clothing due to abrasion.
The abrasion test was carried out according to ISO 12947-2 (9 kPa pressure, 5000 cycles) using the Martindale abrasion tester (figure 2, *c*) and standard wool fabric was used as the abrasive material. The reflection performances of the worn samples were tested.

***Washing***

Test samples were washed according to EN ISO 6330-2000 Method 2A. After washing, the reflective performances of the samples were tested.
Flexing: Flexural tests of the samples were carried out according to EN ISO 7854 Method A. The reflective performance of the samples was measured after 7500 cycles. The device on which the test is performed is shown in figure 2, *d*. immediately followed by, 20 hours at –30±2°C).

***UV ageing***

UV ageing was done according to EN ISO 4892 and the samples were kept in the UV ageing test chamber (figure 2, *e*) for 50, 100, 150 and 300 hours (max. 35 watts/cm$^2$) and then their reflective performances were measured.

***Elongation***

To see the effect of the woven tapes used on the elongation of the knitted fabric, an elongation test was carried out on knitted fabrics according to TS 10985. Three specimens were tested for each fabric sample. The samples were prepared separately from knitted without tape, with sewn tape and with adhesive tape. Three specimens were tested for each fabric sample.

## RESULTS AND DISCUSSIONS

### Findings of fabric properties

Table 1 shows the properties of the fabrics used in the study.

Table 1

CHARACTERISTICS OF THE FABRICS USED IN THE STUDY

| Fabric type | Material | Yarn count | Weight (g/m$^2$) |
|---|---|---|---|
| Knitted fabric | 100% Polyester | 70 denier | 100.48 |
| Woven fabric | 100% Polyester | 70 denier | 88.30 |

### Findings regarding the determination of retroreflective performances

The retroreflective performance values of the reflective tapes used individually and as sewn or adhered to the fabric and after various effects are shown in table 2 and the graph of these values is shown in figure 3.
From the data obtained, it is seen that the retroreflective performance of the adhesive tape is lower than the performance of the sewn tape. It is also seen that the reflection performance of the tapes decreases when they are sewn or adhered to the fabric.
It is understood from the measurement results that there is not much decrease in the reflective performance of the samples after washing.
When the reflective performances of the samples were examined after the abrasion, it was observed that the reflective performance of the samples decreased between 18–22%. Among these samples, it is seen that the decrease in reflection performance is the most in the samples with woven tape.
When the reflection performances of the samples are examined after stretching, it is seen that the reflection performance of the samples decreases between 5–12%. The decrease in retroreflective performance after various effects in reflective tapes also reduces the service life of these garments.

### Findings for the determination of retroreflective performances after UV ageing

The samples were kept in a UV cabinet for 50, 100, 150 and 300 hours. It was observed that there was

Table 2

RETROREFLECTIVE VALUES OF THE SAMPLES AFTER WASHING, ABRASION AND FLEXING

| Samples | Retroreflectivity (cd/lx.m$^2$) | Retroreflectivity after washing (cd/lx.m$^2$) | Retroreflectivity after abrasion (cd/lx.m$^2$) | Retroreflectivity after flexing (cd/lx.m$^2$) |
|---|---|---|---|---|
| Self-adhesive reflective tape | 310 | 297.6 | 251.3 | 272 |
| Inadhesive reflective tape | 405 | 394.6 | 317 | 387.75 |
| Knitted fabric with sewn tape | 378.25 | 402 | 322 | 366 |
| Knitted fabric with adhesive tape | 289.75 | 288.3 | 237 | 278 |
| Woven fabric with sewn tape | 397 | 399.25 | 335.33 | 377.33 |
| Woven fabric with adhesive tape | 307 | 286.75 | 244 | 279 |

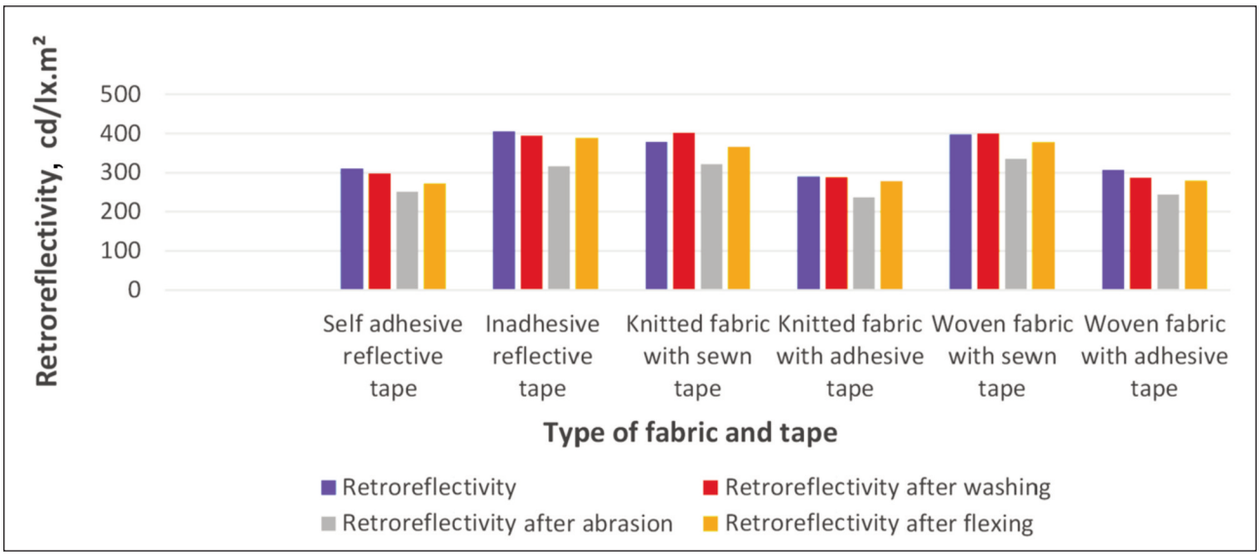



Fig. 3. Retroreflective performances of samples after various effects

no change in the measured retroreflective values of the samples at the end of each waiting period.

### Findings of elasticity values of samples

As can be seen in table 3 and figure 4, the elongation amount of the knitted fabric is very high. Woven reflective tape is used in both knitted and woven fabrics in the market. In this study, the elasticity test was applied only to knitted fabric samples and knitted fabric samples to which tape was attached since it is thought that the woven tape will restrict the stretching of the knitted fabric. As a result, it appears that sewing or glueing the reflective tape limits the elongation of the knitted fabric.

Table 3

| ELASTICITY VALUES OF THE SAMPLES | |
|---|---|
| **Sample** | **Elongation rate (%)** |
| Knitted fabric | 30.7 |
| Knitted fabric with sewn tape | 0.77 |
| Knitted fabric with adhesive tape | 1.53 |

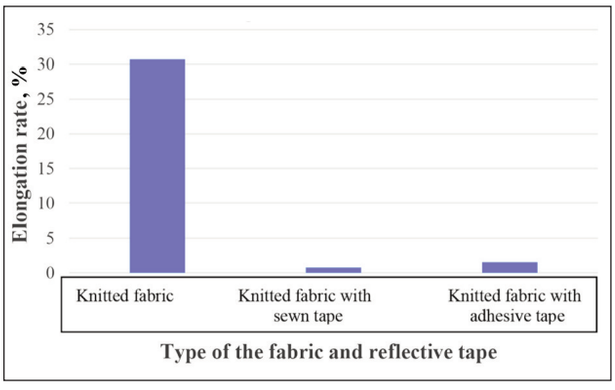



Fig. 4. Elongation values of samples

## CONCLUSION

The importance of high-visibility clothing and textiles is increasing day by day. While these clothes were used for protection at the beginning, they have started to be used in many areas from wedding dresses to clothes worn in performing arts, to decoration products. The materials used in the production of these products, when left under the sun or any artificial light for a certain period, give light that can be seen clearly in the dark and provide visibility. Although the glow produced by these materials gradually decreases after a while, when left in the sun or artificial light source, it can store the light again and give light in the dark.

High-visibility clothing is classified as visually striking personal protective clothing to reduce the risk of death or injury in traffic accidents. The fact that the traffic is more intense day by day leads to congestion and therefore to greater risks. Especially at night and during harsh weather conditions, the risks increase even more. Wearing high-visibility clothing can also reduce or prevent these risks.

In this study, the change in the high visibility of the high-visibility samples created with different fabrics and different tape types was evaluated after various effects.

When the samples were examined, it was seen that the retroreflective value of the non-adhesive tape was higher than the retroreflective value of the self-adhesive tape. After the washing process, the reflective value of both tapes decreased by 3–4%, and after the rubbing process, it was seen to decrease by approximately 20%.

It has been observed that when the tapes are sewn or glued onto knitted or woven fabric, their retroreflective values are reduced by 6–7%. However, after the washing process, it was observed that the reflective value of the tape stitched to both knitted and woven fabrics increased by 5–6%. It was observed that the

reflective value of the tape adhered to both knitted and woven fabrics decreased after washing.

While the reflective values of the tapes sewn or adhered to the knitted fabric decreased by 15–26% after abrasion, the reflective value of the tapes sewn or adhered to the woven fabric decreased by 19–20%. This difference is due to the flexibility of knitted fabrics.

It was observed that there was not much change in the reflective performance values of the samples after washing and ageing in the UV ageing test chamber for 300 hours.

When the elasticity value of the knitted fabric is examined, it is seen that the woven reflective tapes restrict the movement of the person and reduce comfort, which is one of the most important features especially in protective clothing. Therefore, the production of reflective tapes with a more flexible structure produced with the knitting technique should be considered to increase the comfort of clothing.

The decrease in retroreflective performance after various effects in reflective tapes reduces the protective feature of the garment, thus reducing its useful life.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