IMPROVING SUSTAINABILITY OF SEATBELT USING RECYCLED POLYESTER

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ABSTRACT

This project aims to design and develop a sustainable seatbelt by replacing conventional 100% polyester yarn with recycled polyester yarn. With sustainability becoming a growing priority in the automotive industry, this initiative focuses on reducing the environmental impact of seatbelt manufacturing without compromising safety and performance. The process begins with reverse engineering an existing seatbelt made from 100% polyester to gain a thorough understanding of its structure, material properties, and mechanical behavior. This step is essential, as there is limited published research on the application of recycled polyester in seatbelt production. Following the analysis, the team will identify and source recycled polyester yarns that align with environmental goals while still meeting strict safety requirements. Various blend ratios of virgin and recycled polyester will be tested to match the tensile strength, durability, and elasticity of the original material. This evaluation is crucial to ensure the recycled materials do not compromise the seatbelt's safety performance. Once the optimal blend is selected, a prototype seatbelt will be constructed and subjected to testing based on relevant automotive safety standards. The project ultimately aims to create a safe, reliable, and eco-friendly alternative to traditional seatbelt materials.

Keywords: - *Sustainability, Reusability, Efficiency, Standards.*

1. INTRODUCTION

The automotive industry is progressively acknowledging the critical need for sustainability, especially in the production of safety components like seatbelts. Conventional seatbelts are predominantly made from petroleum-based materials, which exacerbate environmental degradation and contribute to significant waste. In response, our project seeks to design and develop a sustainable seatbelt using recycled polyester yarn. This innovative approach not only aims to minimize the ecological footprint associated with seatbelt production but also meets the increasing consumer demand for eco-friendly products.

By integrating recycled materials, we reduce reliance on virgin resources, thereby conserving energy and decreasing greenhouse gas emissions. Additionally, our project aligns with three Sustainable Development Goals (SDGs): Goal 12 (Responsible Consumption and Production), which promotes sustainable practices in manufacturing; Goal 13 (Climate Action), which encourages initiatives to combat climate change; and Goal 9 (Industry, Innovation, and Infrastructure), highlighting the importance of sustainable industrialization and fostering innovation for sustainable practices.

1.1 PROJECT OBJECTIVE

The primary objective of this project is to design and develop a sustainable seatbelt that replaces 100% polyester yarn with recycled polyester yarn. This initiative seeks to maintain safety and performance standards while promoting sustainability in automotive manufacturing.

1.2 SCOPE

1. Reverse Engineering: Analyzing an existing 100% polyester seatbelt to understand its construction, specifically its herringbone structure with 20 picks per inch and 152 ends per inch.

2. Material Selection: Identifying and sourcing suitable recycled polyester yarn and other materials that meet our sustainability criteria.

3. Product Development: Constructing a prototype of the sustainable seatbelt based on the findings from the reverse engineering phase.

4. Testing and Compliance: Conducting rigorous testing to ensure the prototype adheres to relevant safety and performance standards.

This project ultimately aims to contribute to a more sustainable automotive industry while ensuring passenger safety.

1.3. CHALLENGES

1. Material Sourcing

Sourcing high-quality recycled polyester can be challenging due to limited availability, quality variability, and ensuring reliable supplier partnerships.

2. Regulatory Compliance

Seatbelt design must meet strict safety standards and certifications, ensuring recycled materials comply with environmental regulations and testing requirements.

3. Manufacturing Processes

Manufacturing with recycled polyester may require new processing technologies, quality control adjustments, and potential cost increases compared to virgin materials.

4. Customer Acceptability

Consumer perceptions of recycled materials can impact acceptability, necessitating education on quality and performance to build brand trust.

5. Performance & Durability

Ensuring recycled polyester meets safety, strength, and longevity requirements involves rigorous testing and validation for consistent performance in real- world conditions.

2. LITERATURE REVIEW

We have attached the collected literature insight with corresponding references.

S.No	REFERENCES	INSIGHTS
1.	Is polyester bad for the environment.[4]	Yes, **polyester** is **bad** for the environment. It is a type of plastic that takes a **long time** to **decompose** and releases significant carbon emissions during production.
2.	Virgin polyester vs recycled polyester clothing.[5]	**Recycled polyester** is much **better** than virgin polyester from an environmental point of view
3.	Virgin polyester vs recycled polyester clothing.[5]	While it has the **same strength** and **elasticity**, it brings several sustainable benefits because it bypasses its petroleum-based production process.
4.	Virgin polyester vs recycled polyester.[6]	**Recycled polyester** is an **alternative** and **sustainable option** to virgin polyester since the production does not depend on petroleum (non-renewable source) as a raw material. Thus, we would reduce our reliance on crude oil to continue developing on sustainable and environmentally friendly.
5.	Virgin polyester vs recycled polyester clothing.[5]	To put the virgin polyester vs recycled polyester debate into perspective, the latter reduces: energy use by 50%, CO2 emissions by 75%, water consumption by 90%, plastic waste: 1 kg of recycled polyester saves 60 plastic bottles.
6.	What are the pros and cons of recycled polyester.[7]	Recycled polyester is almost the same as virgin polyester in terms of quality, but its production requires 59 percent less energy compared to virgin polyester.
7.	Tensile behavior of virgin and recycled polyester non-woven filter fabrics.[8]	While we observed some minor differences in the results, the overall conclusion remains clear: there is no evidence suggesting that mechanically recycled PET textiles have any significant differences or deficiencies regarding microplastic fiber and fibril formation and release potential when compared to virgin polyesters
8.	An elastic weaved belt to sustain the human body.[9]	The study indicates that improving seatbelt sustainability involves reducing weight, enhancing recycling rates, and optimizing production processes to minimize environmental impacts throughout its life cycle.
9.	lifecycle assessment of Autoliv front seatbelt.[10]	The invention focuses on a woven elastic belt using polyurethane threads, designed to support the human body, potentially applicable in sustainable seatbelt designs.
10.	Code of federal regulations.[11]	Seatbelt testing standards.

Table 2.1. Insights from Literature

11. VIRGIN VS RECYCLED POLYESTER

	Elongation(%)		Tenacity (gmf/tex)	
	Virgin	Recycled	Virgin	Recycled
Mean	10.81	9.14	34.32	32.08
C.V%	10.28	9.17	6.58	10.68

Table 2.2. Elongation & Tenacity for 75 Denier Virgin & Recycled Polyester Fiber.[1]

	Elongation (%)		Tenacity (gmf/tex)	
	Virgin	Recycled	Virgin	Recycled
Mean	12.92	10.26	23.55	20.24
C.V%	26.75	33.10	23.02	29.13

3. METHODOLOGY

1. REVERSE ENGINEERING: The project begins with reverse engineering an existing 100% polyester seatbelt to understand its properties and construction. This analysis includes examining its weave structure, tensile strength, and durability characteristics. Initial testing was conducted at SITRA and TITSC to gather baseline performance data.

2. MATERIALSELECTION: Following the reverse engineering phase, we will identify and select sustainable materials, focusing on recycled polyester yarn and fiber. Our approach may involve blending virgin polyester with recycled polyester in specific ratios to achieve the desired mechanical properties while ensuring compliance with established testing and safety standards.

3. PRODUCTDESIGN: The design of the sustainable seat belt will be informed by the material composition. We aim to re-engineer the original design closely, avoiding major alterations to ensure that the functionality and safety characteristics remain intact.

4. CONSTRUCTION: Once the design is finalized, we will construct a prototype of the sustainable seatbelt using the selected materials and specified design parameters.

5. TESTING AND COMPLIANCE: The final product will undergo comprehensive testing to verify its adherence to relevant safety and performance standards. This phase is crucial to ensure that the sustainable seatbelt meets the necessary requirements for reliability and effectiveness in automotive applications.

Through this structured methodology, the project aims to deliver a high-quality, eco-friendly seatbelt that contributes to sustainability in the automotive industry.

3.1. FLOWCHART

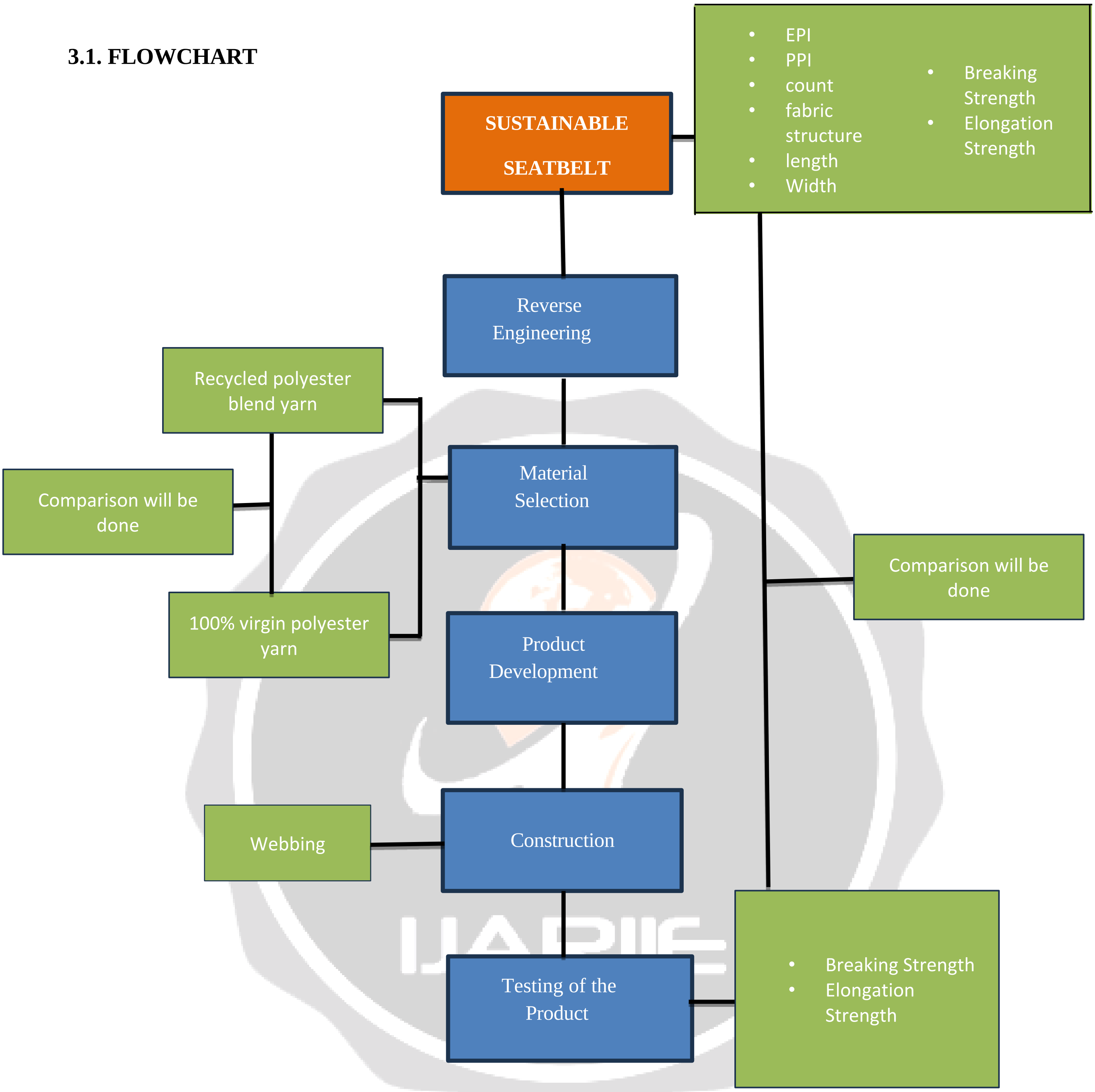

Fig 3. Process of Re-engineering.

4. TESTING

Multiple tests have been carried out to investigate the properties of the existing 100%polyesterseatbelt,as previous data and literature on its characteristics and structure were limited. This comprehensive analysis aims to enhance our understanding of its performance and safety features in various conditions.

List of tests carried out at SITRA (South Indian Textile Research Association)on the given 100% SEATBELT is as follows:

- Average warp and weft yarn count

- Warp and weft fiber identification
- Ends per inch
- Picks per inch
- GSM
- Weight per linear meter
- Fabric width
- Total ends
- Weave

Test that has been given to conduct at TITSC (Technical and Innovative Textile Solution Center)
Tensile Strength

4.1. TESTING STANARDS FOLLOWED

1. IS1969-2(2010)
2. IS15140/2018
3. AUTOMOTIVERESEARCHASSOCIATIONOFINDIA (AIS- 005/2000)

Indian Standard (IS) 1969 pertainsto **"Automobile seatbelts for passenger cars"** and is divided into multiple parts, one of which is
IS1969-2 (2010).
The standard covers various tests such as:
Static load testing: This ensures that the seat belt can withstand a certain amount of force (load) without breaking.

IS15140/2018 outlines the requirements for **seatbelt installation and their performance characteristics**.
The standard defines criteria for:
Seatbelt strength: It specifies the minimum load requirements that the seat belt must handle without failure.

AIS-005/2000 by the **Automotive Research Association of India (ARAI)** is an Indian regulation that defines the **requirements for seatbelt systems** in automobiles.
The standard covers**:**
Testing protocols: Detailed testing methods for evaluating seatbelt strength, durability, and effectiveness in various accident scenarios.

5. RESULTS AND DISCUSSIONS

5.1. YARN AND FABRIC ANALYSIS

Assess Particulars	Original
Average Warp Count (Denier)	1754.1(108 Filaments)
Average Weft Count (Denier)	560.06 (84 Filaments)
Fiber Identification	
Warp yarn	Polyester
Weft yarn	Polyester
Ends per inch	152
Picks per inch	20
GSM	1267.9
Weight per linear meter (g)	59.6
Fabric width (cm)	4.7

Total ends	280+1loopend
Weave	Enclosed in separate sheet

Table 5.1. Properties of original seatbelt

The analysis of the existing 100% polyester seatbelt provided critical data regarding its structural properties, essential for both performance evaluation and the sustainable redesign process.

5.1.1. REPRESENTATION OF SEATBELT WEAVE STRUCTURE

1	X	X			X	X			X	X			X	X			X	X		
2		X	X		X			X		X	X		X			X		X	X	
3			X	X			X	X			X	X			X	X			X	X
4	X			X		X	X		X			X		X	X		X			X
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4

Fig 5.1. 2/2 TWILL HERRINGBONE

Fig5.2. Original Seatbelt

5.1.2. RESULT AND DISCUSSION

Yarn Count:
Warp Yarn: The average count is754.1 denier with 108 filaments. This indicates a robust and thicker yarn, which significantly contributes to the seatbelt's strength and resistance to tensile forces. A higher denier in the warp yarn suggests that it is well-suited for handling the loads and stresses encountered in automotive safety applications.

Weft Yarn: The average count is 560.06 denierwith84 filaments. The lower denier in the weft yarn suggests increased flexibility, which is crucial for comfort. This balance of strength in the warp and flexibility in the weft is vital for ensuring user safety without sacrificing comfort during everyday use.

Density Measurements:
The seatbelt features 152 ends per inch and 20 picks per inch. This high-end count indicates a dense weave structure that enhances overall strength and safety. The relatively lower pick count allows for some degree of flexibility, which is essential in applications where the seatbelt needs to conform to various body shapes while remaining secure.

Grams per Square Meter (GSM):
The GSM measurement of1267.9 indicates a substantial weight, which contributes to the seatbelt's durability. Higher GSM typically correlates with improved performance in terms of load-bearing capacity and resistance to wear and tear, essential qualities for a safety component.

Total Ends:
The total count of280 ends plus1 loop end reinforces the robustness of the weave. The inclusion of the loop end is critical

for the seatbelt's functionality, ensuring effective deployment and retraction mechanisms during use, which are vital for passenger safety.

5.2. TENSILE STRENGTH TEST-TITSC

Test Specimen	Test Results (kgs)	Standard	Results
S-1	2156.32	1361to2722Kgs	PASS
S-2	2256.15		PASS
S-3	2198.27		PASS
S-4	2253.09		PASS
S-5	2143.39		PASS
Average	2201.44		PASS

Table 5.2. Tensile strength results of 5 samples.

5.2.1. RESULT & DISCUSSION

- The seatbelt specimens (S-1toS-5) have tensile strength values ranging from 2143.39 kgf to 2256.15 kgf.
- The average tensile strength is 2201.44kgf.
- The seatbelt specimens meet the minimum tensile strength requirements of AIS 005/2000.
- The seatbelt material is strong enough to withstand the required load and is approved for use.

6. REENGINEERED SEATBELT

6.1. CONSTRUCTION

6.1.1. MATERIAL PROCUREMENT

For the seatbelt construction, 100% recycled filament from Alliance Fibres Ltd., Gujarat was sourced. The required specifications were 1754 deniers and 560 deniers, but due to supply constraints, only 400 deniers and 250 denier sample cones were available. We utilized two 500g cones of the recycled filament for the webbing process, ensuring material performance was evaluated against safety standards.

S.no	Material	Specs
1.	Warp filament yarn	400 Deniers
2.	Weft filament yarn	250 Deniers

Table 6.1. Technical Specifications of Yarns

6.1.2. WEBBING

The tape webbing of the reengineered seatbelt was produced at Annur Tapes, as the needle loom could only accommodate a different weave, while the required structure was a herringbone pattern.

6.2. YARN AND FABRIC ANALYSIS

Assess Particulars	Results
Average Warp Count (Denier)	393.5 (28 Filaments)
Average Weft Count (Denier)	252 (21Filaments)
Fiber Identification	
Warp yarn	Recycled polyester
Weft yarn	Recycled polyester
Ends per inch	36
Picks per inch	24
GSM	433.75
Fabric width(cm)	4.0
Thickness(mm)	0.90
Weave	Enclosed in separate sheet

Table6.2. Evaluation of Fabric Characteristics

This is the structure specification analysis of the100%recycled reengineered seatbelt.

6.2.1. REPRESENTATION OFSEATBELTWEAVE STRUCTURE

14		x	x	x	x	x	x	x	x
13		x	x	x	x	x	x	x	x
12		x		x		x		x	
11		x		x		x		x	
10		x	x	x	x	x	x	x	x
9		x	x	x	x	x	x	x	x
8			x		x		x		
7			x		x		x		
6		x	x	x	x	x	x	x	x
5		x	x	x	x	x	x	x	x
4		x		x		x		x	
3		x		x		x		x	
2		x	x	x	x	x	x	x	x
1		x	x	x	x	x	x	x	x

		1	2	3	4	5	6	7	8

Fig 6.2. Re-engineered Seatbelt
Fig 6.1. Broken Twill Weave

6.2.2. RESULT INTERPRETATION

Filament count:
Warp: Running lengthwise in the fabric, have an average count of393.5 denier, indicating they are relatively thick. This yarn is composed of 28 individual filaments, with each filament contributing to the overall strength and durability of the fabric
Weft: Which runs widthwise in the fabric, have an average count of 252 denier. While slightly thinner than the warp yarns, these weft yarns are still substantial in thickness. Composed of 21 individual filaments.

GSM (Grams per Square Meter):
The fabric has a GSM (grams per square meter) of433.75, indicating a heavy weight. This measurement reflects the fabric's overall density and thickness. A higher GSM typically suggests better durability and a more substantial feel, making this fabric suitable for heavy-duty applications such as automotive interiors or seat covers.

Total Ends:
The fabric has 36 ends per inch, which refers to the number of warp yarns in one inch of the fabric. This relatively dense warp count contributes to the fabric's stability and tensile strength.

Dimensions:
The fabric has 24 picks per inch, referring to the number of weft yarns present in one inch of fabric length. This density of weft yarns contributes to the overall balance and texture of the fabric. The moderate number of picks per inch ensures a well-structured fabric that is not too loose or too tight, providing an ideal balance between flexibility and strength.

6.3. TENSILE STRENGTH TEST-TITSC

Test Specimen	Test Results(kgs)	Standard	Results
S-1	1498.15	1361to2722Kgs	PASS
S-2	1492.45		PASS
S-3	1495.37		PASS
S-4	1491.45		PASS
S-5	1492.18		PASS
Average	1493.93		PASS

Table 6.3. Tensile Strength Results of 5 Samples.

6.4. SUMMARY OF TEST RESULT

- The seatbelt specimens (S-1toS-5) have tensile strength values ranging from 1498.15kgf to 1492.18kgf.
- The average tensile strength is 1493.93kgf.
- The seatbelt specimens meet the minimum tensile strength requirements of AIS 005/2000.
- The seatbelt material is strong enough to withstand the required load and is approved for use.

7. SPECIFICATION COMPARISON

Assess Particulars	Original	Re-engineered
Average Warp Count (Denier)	1754.1(108 Filaments)	393.5(28 Filaments)
Average Weft Count (Denier)	560.06(84 Filaments)	252(21Filaments)
Fiber Identification		
Warp yarn	Polyester	Recycled polyester
Weft yarn	Polyester	Recycled polyester
Ends per inch	152	36
Picks per inch	20	24
GSM	1267.9	433.75
Fabric width(cm)	4.7	4.0
Thickness(mm)	1.25	0.90
Weave	Enclosed in separate sheet	Enclosed in separate sheet

Table7.Comparison Between Original and Re-engineered Seatbelts.

8. COMPARISON OF CAR SEATBELTS

Model	Curb Weight (kg)	Production (2023)	Total Seatbelts (2023)	Seatbelts (m)
Opel Corsa	980–1,200	225,000units	1,125,000	3,375,000
Toyota Yaris	960–1,368	166,925units	834,625	2,503,875
Peugeot 208	1,080	230,800units	1,154,000	3,462,000

Table8. Comparing the Annual Production of Cars and Seatbelts in 2023.

Peugeot 208, Opel Corsa, and Toyota Yaris were compared for their seatbelt usage. Since more cars were made, more seatbelts were needed. Peugeot used the most, followed by Corsa and Yaris. Each car needs around five seatbelts, and all together, they used more than 9 million meters of seatbelt material in 2023. This shows that making so many seatbelts require a lot of resources. Using recycled materials for seatbelts is a smart way to reduce waste and support a cleaner environment.

9. COSTING

Aspect	Virgin Polyester	Recycled Polyester
Cost per kg	₹90 – ₹120	₹110 – ₹140
GSM (Seatbelt Fabric)	1268	434
Seatbelt Width	4 cm (0.04 m)	4 cm (0.04 m)
Weight per Meter	50.72 g	17.36 g
Cost per Meter	₹5.33	₹2.17
Material per Seatbelt	60 g	60 g
Cost per Seatbelt	₹6.30	₹7.50
Raw Material Source	Petroleum-based	Waste plastic (PET bottles)
Environmental Impact	High	Low
Energy Usage	100%	59% less
Carbon Emissions	High	Up to 75% lower
Water Consumption	High	Up to 90% less

Table 9. Estimating Of Virgin Polyester and Recycled Polyester.[2][3]

Recycled polyester is better for the environment, with less energy, water use, and lower carbon emissions. However, it costs slightly more per seatbelt than virgin polyester.

10. CONCLUSION

This project demonstrates that recycled polyester can be used to create sustainable seatbelts without compromising safety. By analysing the structure and performance of standard seatbelts, a prototype was developed using recycled yarn, confirming its suitability for automotive safety. The recycled seatbelt met all required tensile strength benchmarks, proving it can perform as well as traditional materials. While some differences in filament counts and fabric density occurred due to sourcing constraints, the final product maintained its functional integrity. This initiative helps reduce plastic waste and lessens dependence on petroleum-based resources, supporting key sustainability goals like responsible production and green innovation. Overall, the project proves that recycled polyester is a viable material for safety-critical applications and encourages further exploration of eco-friendly practices in the automotive industry and beyond.

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