



Latex from the Hevea tree was used to produce rubber and provide the first truly viable alternative to leather for footwear soling. CREDIT: SHUTTERSTOCK

Why don't soling materials die?

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For many thousands of years leather remained the main soling material for all types of footwear with, in certain places, wood, reeds, papyrus, sisal and other natural products also being used. This situation continued until the development of reliable rubber soles in the 1930s. It had initially begun some years earlier with the use of soles cut from sheets of natural crepe rubber, a material formed from natural latex tapped from rubber trees and lightly smoked to improve its properties. Except for having low levels of resistance to oil and solvents, these natural rubber soles were both durable and flexible.

Experiments to improve the properties of natural rubber had been ongoing since the very earliest efforts in the late 18th century to improve them by vulcanisation, but it was only in the late 19th century that serious progress was made. It took even more effort in the 20th century and the introduction of synthetic rubber based

on styrene-butadiene (SBR) in the late 1930s before consistent high quality vulcanised rubber soles could be produced in large volumes. For instance, the first reproducible Vibram SBR units were launched onto the market in 1937 and were made possible by a blend of developments in chemistry, machinery and moulds.

After this, the only change for several decades was the introduction of resin rubber sheeting, which is in fact a harder version of standard vulcanised rubber compounds. It was the huge increase in growth of oil-based polymeric compounds through the 1960s and 70s that led to an explosion of new soling materials during this

Table 1 – Introduction of primary soling materials.

1930	1940	1950	1960	1970	1980	1990	2000	2010
L	L	L	L	L	L	L	L	L
NR	N	N	N	N	N	N	N	N
VR	VR	VR	VR	VR	VR	VR	VR	VR
	RR	RR	RR	RR	RR	RR	RR	RR
			PVC	PVC	PVC	PVC	PVC	PVC
				PU	PU	PU	PU	PU
				TPR	TPR	TPR	TPR	TPR
				TPU	TPU	TPU	TPU	TPU
					EVA	EVA	EVA	EVA
						LR	LR	LR
							POE	POE
								?

period. As *Table 1* shows, four new major materials were introduced: PVC, PU, TPR and TPU. Since then, the rate of introduction has slowed to only one new material per decade and none at all in the 2010s. However, the major chemical companies are working on new polymeric materials and, although it is expected that new additions to this list of soling compounds will arrive in the next five years, none have so far successfully come to market to any significant degree.

Table 2 provides a brief description of the major properties and uses of these eleven soling materials and is included in order to try and explain why they all still maintain a position in the soling market. What is most interesting, is why none of these materials have disappeared from the market as new ones have been introduced.

The information in *Table 2* shows quite clearly that there are very large differences between the various soling materials and this is one of the reasons why they all still continue to be used. It is not the dominant reason however. *Table 3* shows the growth of the world's population, footwear production and overall soling market for the years 1960 to 2010, together with a breakdown into the individual eleven soling compounds.

It is quite clear that the increase in demand has been enormous, with a growth of 28% in world population from 1995 to 2015 but an eye watering one of 78% for footwear and soling materials. One of the answers to the question posed in the title of this article, is therefore quite simply that there is too great an increase in demand for any of them to disappear and in conjunction with their differences in properties, all find a market in the broad spectrum of footwear that now abounds around the world. Another factor is that, unlike the situation decades ago when a particular fashion would sweep through the footwear market, all styles continue to be in production all of the time. There are no on-off seasons so every material has a use.

These eleven primary soling materials are also often used in combination so there are in fact many more soling solutions available to the shoe designer/manufacturer. Some of the more common combinations are, VR/VR, VR/EVA, VR/PU, PU/PU, TPU/PU, TPU/TPU, PVC/PVC,

Table 2 – Properties of soling materials.

Material	Properties
L	The original natural soling material and still in use. Comes in the form of skins, so soles can be cut out and trimmed to shape. Leather has poor wear properties compared to many of the other soling compounds but has the best 'natural' image of all.
NR	A natural material based on latex obtained from Hevea rubber trees and normally sold in sheet form as 'Plantation Crepe'. Poor properties as supplied with very little resistance to solvents and oils. Also used at low levels in conjunction with SBR to make VR and at high levels to produce LR. Forms the basis of the natural concept for rubber.
VR-SBR	A tough, hard wearing product with a natural image even though mainly synthetic. Supplied as preformed blanks partially vulcanised so some storage problems. Needs high heat to complete the final vulcanisation step.
RR	A variant of VR which has a high hardness and a particular 'boardy' feel obtained by high loadings of fillers. Sold as sheets, often profiled, to make thin soles for women's court and thin-soled casual shoes.
PVC	A definite down market 'plastic' image but low cost and easy processing. Properties drop off rapidly as density is reduced. Has dominant share in some markets due mainly to price.
PU	Offers broadest range of end effects but is seen as difficult to use due to its chemistry. PU is able to provide the broadest range of densities and hardnesses of all the soling materials. A tough high performance material only surpassed by TPU but needs special machinery to process it and waste is not recyclable.
TPR-SBS	Known for its high tactility, there can however be problems with solvent/oil resistance and bonding. Low density products not very successful so far due to poor properties. Has a strong association with natural products due to the inclusion of rubber in the name and is the only thermoplastic to have this image.
TPU	High performance material mainly used for downhill ski boot shells, soccer boot plates and top-pieces for women's court shoes. Now beginning to penetrate the outsole market and has been blown successfully to 0.6 g/ml whilst retaining good properties.
EVA	Major feature is ability to be blown to very low densities whilst still maintaining reasonable properties. Used in a wide range of applications including midsoles for sports shoes and hard wearing outsoles for casual shoes and sandals, etc.
LR	Key feature is softness and high tactility. Developed as a vulcanised rubber answer to TR. Some problems with foot stability at low hardness with low tear strength and resistance to solvents in adhesives and finishes.
POE	By adjusting the production process it is possible to create a polyethylene with elastomeric properties instead of the normal plastic handle and feel of conventional polyethylene. There is now a range of POEs from different suppliers that should fit into the soling market. They have struggled to find a niche due to problems of bonding and colouring the compounds. They are commonly used in conjunction with EVA for midsoles.

Table 3 – Major soling materials 1960–2010.

		1960	1970	1980	1990	2000	2010
World population	(Millions)	5,701	6,065	6,477	6,891	7,30	7,698
Footwear production	(Million Pairs)	13,438	15,565	19,466	21,566	23,941	27,283
Footwear soling	(Ktonnes)	6,484	7,484	9,411	10,395	11,500	13,085
L	"	453	495	584	622	701	797
NR	"	309	352	423	453	482	549
VR-SBR	"	1,576	1,780	2,216	2,405	2,637	2,990
RR	"	298	326	370	406	443	503
PVC	"	1,652	1,948	2,538	2,793	3,059	3,464
PU	"	260	408	542	636	711	821
TPR	"	961	1,072	1,326	1,479	1,665	1,898
TPU	"	89	98	128	167	200	225
EVA	"	553	625	787	889	1,000	1,147
LR	"	259	283	350	368	402	462
POE	"	1	7	17	37	51	58
Other	"	73	90	130	140	149	171
Total	"	6,484	7,484	9,411	10,395	11,500	13,085

Table 4 – Segment definitions.

Sports	One piece	Downhill ski boot shells, roller-blade boots, ice hockey boots, sailing or wind surfing shoes. Except for the last item, generally made from high hardnesses grades of materials such as TPU and TPR.
Sports	Plated	Hard outer soles for soccer boots, rugby boots, baseball shoes, running track shoes, golf shoes. Generally made from two or three components using high hardness grades of TPU or Hytrel.
Sports	Running/ aerobic	General running shoes, aerobic shoes, cross training shoes. Often referred to as white shoes but can be made in a variety of constructions and colours.
Boots	Work/ walking	Robust styles of boot with strong functional elements but also includes secondary use for casual/fashion wear. Covers safety footwear as well as walking.
Boots	Fashion	Consciously designed to meet fashion needs, far less functional than other two areas. Knee high and ankle boots with a wide range of upper materials. Currently also thick soled styles.
Boots	Wellingtons	Footwear with sole and upper (part or all) produced from soling materials. Covers wellington boots, snow galoshes and sailing boots.
Casual	Ath/leisure	Casual footwear designed along the same lines as sports footwear and including 'brown' shoes. Multi-functional styles that can be worn in a range of environments. More fashion orientated.
Casual	Business/everyday	Casual footwear specifically designed for outdoor country use including walking, hiking, etc. Has to have a higher degree of functionality than ath/leisure or everyday. Tend to have a rugged look.
Casual	Fashion	Casual styles that can be worn in an everyday situation but with a high fashion content which recently has generally meant thicker soles. Often based on the design concepts of sports shoes but heavily modified.
Formal	Business	Very formal styles to be worn in a strict business environment normally with suits (men and women) usually black or dark brown and thin soled.
Formal	Court	Women's medium to high heeled shoes with thin soles, usually leather, resin rubber, TPR or TPU and with TPU top pieces on the heels.
Formal	Leisure	Formal end of casual/formal area involving shoes that are a variant on the business shoe for the more formally minded to wear in a casual situation.
Sandals	Beach	Includes all low cost sandals from flip-flops to thongs and other simple styles normally built up on a basic sole unit. In developed markets almost seen as disposable items but can be basic footwear in under-developed countries.
Sandals	Fashion	Mainly women's ranges and well known from the multiplicity of Italian designs which have been copied all over the world. Known as chappals in India. Simple unit sole often with open thonged upper.
Sandals	Leisure	More robust styles for both men and women including sports sandals, casual-sandals, Jesus-sandals, etc. Sole is more functional and needs to be better quality.
House	Casual	Lightweight style of shoe, often a moccasin, to be worn indoors but also stand some outdoor use. More formal and stylish than a slipper.
House	Slippers	Predominantly for indoor use so sole has only a light functionality and uppers are designed more for comfort than style.
Economic	Basic	Artisanal shoes made by local cobblers who use whatever soling materials are available. So VR includes old car tyres for instance.
Economic	Thongs	Same principle as thonged sandals but having more functionality built in as a primary basic type of footwear and so need to last.

Table 5 – Properties.

Test	Units
Sole substance	(mm)
Weight	(grams)
Volume	(ml)
Moulded density	(g/ml)
Hardness	(Shore A)
Tensile strength	(Mpa)
Elongation	(%)
Tear die C	(kN/m)
Split tear	(kN/m)
Stitch tear	(kN/m)
Abrasion resistance	(mm ³)
Adhesion	(N/mm)
Low temp. flexibility	1-5
Wear durability	1-5
Slip resistance	1-5
Ozone resistance	1-5
UV resistance	1-5
Chemical resistance	1-5
Tactility	1-5
Flexibility	1-5
Smell	1-5
Processability	1-5
Design freedom	1-5

TPR/TPR. In addition, the different materials can be used as inserts or logos in conjunction with other materials. *Table 4* provides a brief definition of one way of looking at the seven major and nineteen minor segments that can be used to divide up the footwear market.

That this is only a relatively coarse segmentation of the footwear market is shown by the fact that it is possible to list over 100 different sports, each of which has a special type of footwear produced for them. So 100 variations is forced into just three sub-segments. A similar range of specialisations could be drawn up for the other segments and sub-segments.

How do shoe makers therefore decide which soling material to use? One way is to look at the overall spectrum of properties for the different soling materials and then carry out a Perception Analysis to see which of the materials gives the best fit to the requirements for a particular design of sole. The range of properties to consider are given in *Tables 5 & 6* and show a segment of a such an analysis. *Table 5* suggests that any choice is complicated

Table 6 – Perception analysis (sports running/aerobic).

						TPR-SBS			PVC			TPU			PU		
Variable Items	Units	Method		Top 5 Weight	Ideal Data	Act Yes	% Fit	Wa	Act Yes	% Fit	Wa	Act Yes	% Fit	Wa	Act Yes	PU % Fit	Wa
Moulded Density	(g/ml)	DIN 53420				1.00			1.20			0.80			0.50		
Weight	(grams)		Max	0.30	550	850	65	0.19	1,020	54	0.16	680	81	0.24	425	129	0.39
Hardness	(Shore A)	DIN 53505	Min		60	60	100	0.00	60	100	0.00	60	100	0.00	60	100	0.00
Tensile	(Mpa)	DIN 53504	Min		6	6	100	0.00	10	167	0.00	12	200	0.00	7	117	0.00
Elongation	(%)	DIN 53504	Min		400	650	163	0.00	410	103	0.00	850	213	0.00	450	113	0.00
Tear Die C	(kN/m)	DIN 53515	Min	0.15	15	30	200	0.30	35	233	0.35	45	300	0.45	12	80	0.12
Tear Split	(kN/m)	DIN 53507	Min		5		0	0.00		0	0.00	8	160	0.00	5.5	110	0.00
Tear Stitch	(kN/m)	DIN	Min		15	15	100	0.00	18	120	0.00	18	120	0.00	15	100	0.00
Abrasion	(mm ³)	DIN 53516	Max		200	180	111	0.00	210	95	0.00	55	364	0.00	170	118	0.00
Adhesion	(N/mm)	DIN	Min		5.0	5.5	110	0.00	5.5	110	0.00	10.0	200	0.00	8.0	160	0.00
Low Temp Flexib		Gehman	Min		-10	-40	400	0.00	-15	150	0.00	-25	250	0.00	-20	200	0.00
Wear Durability	1-5	SATRA		0.25	3	2.5	83	0.21	1.5	50	0.13	4	133	0.33	3.5	117	0.29
Slip Resistance	1-5	SATRA			4	3.5	88	0.00	3	75	0.00	3	75	0.00	3	75	0.00
Ozone Resist	1-5				2	2	100	0.00	3	150	0.00	4	200	0.00	4	200	0.00
UV Resist	1-5				2	2	100	0.00	3	150	0.00	3.5	175	0.00	3.5	175	0.00
Chemical Resist	1-5				2	2	100	0.00	4	200	0.00	3	150	0.00	2.5	125	0.00
Tactility	1-5				4	5	125	0.19	2	50	0.00	3	75	0.00	3	75	0.00
Flexibility	1-5			0.15	4	5	125	0.00	4	100	0.15	4.5	113	0.17	5	125	0.19
Smell	1-5				3	2	67	0.00	3	100	0.00	3	100	0.00	2.5	83	0.00
Processability	1-5				4	4	100	0.00	5	125	0.00	3	75	0.00	3	75	0.00
Design Freedom	1-5			0.15	4	4.5	113	0.17	4	100	0.15	4.5	113	0.17	3.5	88	0.13
Average Percentage Match				1.00			124	1.06		117	0.94		160	1.36		118	1.12

*NOTE: For each sub-segment in Table 5, property factors are selected and given a weighted percentage significance which is used to calculate the WA (weighted average). This is then compared to the % Fit (percentage of ideal) which takes all the properties into account. A comparison can then be made for all the different soling materials and, for each sub-segment, of the percentage of ideal and weighted average values to get an idea of how the different materials compare to each other.

and that over 20 different factors need to be considered before reaching a decision. The properties showing (1-5) are a ranking scheme where 1 is normally a low fit and 5 a high one. Table 6 shows it is possible to highlight five key factors to simplify the analysis.

These properties don't really change very much over time and only need to be looked at again if any new compounds are developed. What does change quite frequently and dramatically is the price structure of all the different soling materials. At the end of the day, therefore, the choice of soling compound to use for a particular application needs to consider the best fit of properties but, more importantly, the overall cost.

The latter depends not only on the price of the soling compounds but also on the cost of producing the units. So for a particular casual shoe design it might be possible to find off-shelf black units produced from VR, TPR, PVC, PU

or blown TPU. If all five soles meet the necessary physical property requirements then the final decision will inevitably come down to price. Therefore the dominant reason that soling materials don't die is cost, as all

the materials come into their own at different times of the design/production cycle over many seasons. There is a position for all existing ones as well as for any new ones that can be developed in the future. 🔴



The Vibram 'Carrarmato' introduced in the late 1930s was the first moulded unit sole and began the revolution in soling systems that has continued ever since and is still in production. CREDIT: VIBRAM