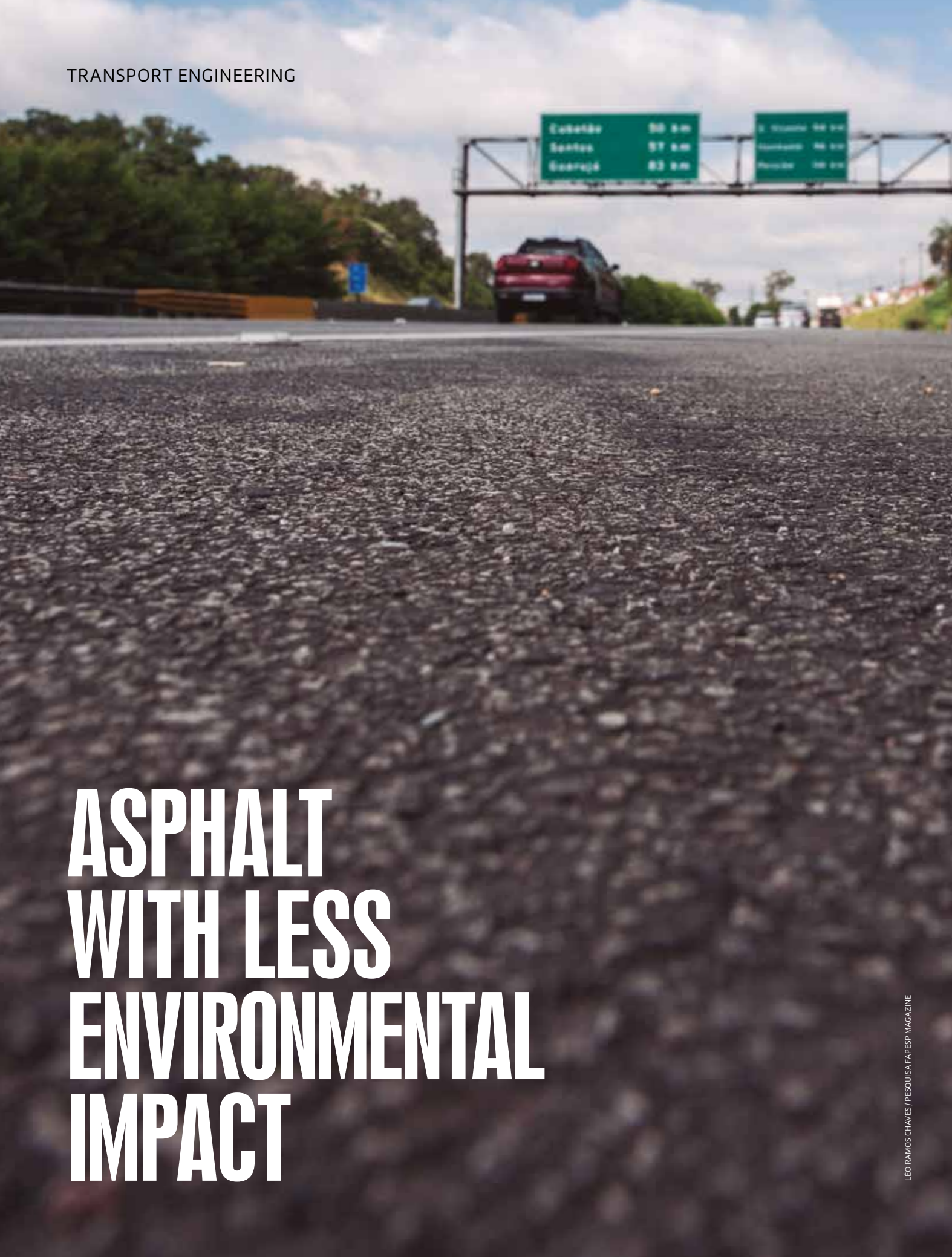

ASPHALT WITH LESS ENVIRONMENTAL IMPACT

LÉO RAMOS CHAVES / PESQUISA FAPESP MAGAZINE

Imigrantes highway, connecting São Paulo to the coast: resurfaced with rubberized asphalt

Reusing tailings from mining, rubble from construction and demolition, and other types of waste reduces the consumption of gravel, natural sand, and petroleum products in paving roads and highways

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Construction of a 425-meter-long experimental lane was completed in March at the Cauê mine, belonging to the mining company Vale, in Itabira, Minas Gerais State. Over the next two years, the site will act as a testing ground to evaluate the use of sand obtained from iron mining tailings as an aggregate for asphalt paving. Aggregates are materials, such as crushed stone, grit, gravel, ground rock, and sand, used in construction. Using sand from mining for this purpose could boost the circular economy by reusing a material traditionally deposited in dams or in dry stacks of tailings, thus reducing the need to mine natural gravel and sand. The circular economy is an economic model that values reducing, reusing, and recycling natural resources that are commonly used in industry.

According to the Brazilian Association of Construction Aggregate Producers (ANEPAC), on average, every kilometer (km) of paved road consumes 9,800 tons (t) of aggregates. "In a preliminary evaluation, it is possible to substitute 7,000 t of aggregates for every km with sand from mining," estimates Sérgio Pacifico Soncim, a civil engineer from the mobility engineering course at the Federal University of Itajubá (UNIFEI) who is responsible for the tests in Itabira.

ANEPAC calculates that in 2022, Brazil will need to extract 400 million tons of sand and 392 million tons of gravel to meet the consumption of 692 million tons of aggregate. Sand is the second most exploited natural resource in the world; water is the first. The United Nations (UN) calculates that between 40 and 50 billion tons of sand are extracted annually, with a significant impact on river and marine ecosystems.

On the other hand, sand represents 80% of tailings from the final stage of iron beneficiation, called concentration, in which the iron is separated from the impurities. At Vale, 55 million tons of sand are produced each year. "We have been studying how to use the material since 2014. Its use in construction allows for environmental gains and generates value for the company," says André Vilhena, New Business manager at Vale.

Using sand from mining as an aggregate for paving came about through a partnership with UNIFEI in 2017 and has already acquired over R$7 million in investments. The first task was to determine the characterization of the iron ore tailings. In this stage, the need to improve the physical and chemical properties of the tailings was identified.

According to Laís Resende, the engineer responsible for the research at Vale, sandy tailings are generated during the iron ore beneficiation process. To transform this material into sand, process routes were created that included concentration, classification, and humidity reduction stages. The sand produced by Vale contains over 92% silica, and its use can increase the lifespan of some materials, such as road paving.

Sand produced in this manner has uniform granulometry. "It is a material with higher quality control than the sand extracted from rivers, which usually contains a significant portion of food waste and decomposed soil. These organic materials can reduce the quality of the applications," says Resende.

Tests performed at UNIFEI showed that sand from mining, due to its uniformity and high silica

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Reused sand from iron mine tailings from Vale's Cauê mine in Itabira, Minas Gerais state

content, increases the performance parameters used to estimate the lifespan of a road by up to 50% compared to conventional sand. It also reduces demand by 6% for petroleum asphalt cement, a petroleum product used as an aggregate binding agent in the surface layer of the paving, called the surface course.

A highway lane is composed of several layers of paving. The most common formation has four layers: subgrade, subbase, base, and surface, which can be asphalt or concrete (*see infographic below*). The 425-meter lane in Itabira will be used to evaluate the results obtained in the laboratory under real conditions and determine the most suitable composition of mining sand in the aggregate mix for each layer.

"The lane was divided into four subsections, each with a different solution in its composition," explains Soncim. A total of 96 sensors were installed, including deformity, pressure, temperature, and humidity meters, and are subjected to constant traffic consisting of vehicles with heavy loads. The studies are being conducted by UNIFEI in partnership with the Alberto Luiz Coimbra Institute for Graduate Studies and Research in Engineering at the Federal University of Rio de Janeiro (COPPE-UFRJ). The institutions are part of the Petrobras Asphalt Technology Network, and the results will be shared with the National Department of Transport Infrastructure (DNIT).

The expectation at Vale is that the test under real conditions will confirm the results from laboratory tests conducted at UNIFEI. In April, the mining company published a study in partnership with the universities of Queensland in Australia and Geneva in Switzerland, which from a technical perspective pointed to the viability of using sand from mining in asphalt paving and tile manufacturing.

OTHER AGGREGATES

Like mining, the steel industry also creates waste that is being reused. The predominant destination for the waste is construction, mainly in cement production, but a portion of the waste is also used in paving. The Brazilian Steel Institute, an entity that unites companies from within the sector, stated in its 2020 sustainability report that approximately 600 kilos of slag are created for every ton of crude steel produced, of which 65% is material from blast furnaces and steel mills with potential for use as construction aggregates. In 2021, Brazil produced 36.2 million tons of crude steel, generating approximately 14 million tons of steel aggregates.

The most used materials in the world as substitutes for natural aggregates in paving are rubble from construction demolition and milled material, the name given to the deteriorated asphalt

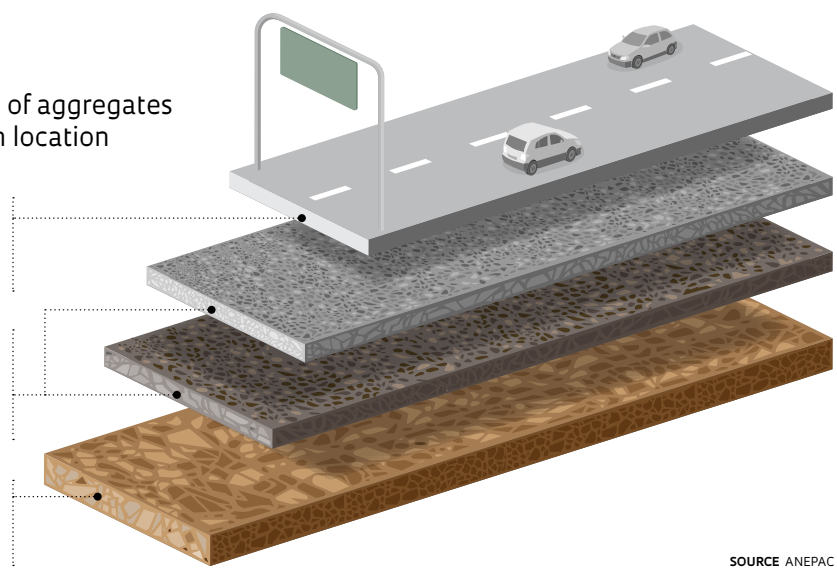
THE GEOMETRY OF A HIGHWAY

The number of layers and the composition of aggregates varies in accordance with the need of each location

1 Asphalt covering
With a thickness of 5 to 10 centimeters, the wearing course is made up of asphalt and a mixture of aggregates

2 Base and subbase
3 Composed of a mix of harder materials, such as gravel and crushed stone, they serve to rectify the ground, stabilize and increase its resistance, and generate support for the upper layer

4 Subgrade
The innermost layer of the road is formed mainly from sand or rock dust and has a similar function to the two layers above it



SOURCE ANEPAC

surface removed from pavements using milling machines. However, these materials are still underused in Brazil.

"There is ignorance and prejudice regarding the use of waste," says civil engineer Liedi Légi Bariani Bernucci, CEO of the São Paulo State Institute for Technological Research (IPT) and former coordinator of the Paving Technology Laboratory (LTP) at the Polytechnic School of the University of São Paulo (POLI-USP). "It is mistakenly believed that it is a low-quality material that will produce bad works and will present problems quickly," says the engineer, who is part of the FAPESP Board of Trustees. "Treated properly, removing leftover wood, plaster, and metal, construction waste is as efficient as natural material."

According to Bernucci, the problem is not the construction companies, which have information about the quality of the recycled material, but the lack of technical preparation by some of the public administrators responsible for contracting the paving. "The construction company follows the contract notice for the service. Few of the technicians in public administration are capable of structuring a contract notice that encourages the use of recycled material and reduces the environmental impact of the work," he explains.

Two types of surfaces are used for the wearing course of roads: one is flexible, made with petroleum asphalt, and the other is rigid, made from Portland cement concrete. Over 95% of works in Brazil use asphalt covering, as in most countries, due to its lower implementation cost, simpler maintenance, and the greater availability of qualified service providers. However, the concrete covering presents greater durability. It is designed to last more than 20 years, whereas the flexible covering lasts for 10 to 15 years. There is no consensus among specialists about using one covering or the other, but the majority suggest using more concrete on roads that receive heavy traffic, such as bus lanes and highways, and for locations where maintenance is difficult and there is a prevalence of asphalt on the other roads. For civil engineer Kamilla Vasconcelos Savasini, current coordinator of the LTP and associate professor of the Department of Transport Engineering at POLI-USP, the production processes of the inputs used in asphalt and concrete have a large environmental impact. An analysis of the production cycle of each work determines the biggest impact of asphalt or concrete, which varies depending on the regional availability of inputs, location, and characteristics of the roads being paved, among other variables.

Asphalt consumption in Brazil reached 1.6 million tons in 2021, according to Petrobras, which is below the yearly average of approximately 2 million tons prior to the COVID-19 pandemic. According to Savasini, every kilometer of asphalt paving with a thickness of ten centimeters on a single 3.5-meter-wide lane of road consumes approximately 50 tons of asphalt. "Reducing the environmental impact of a road or urban work can be done by reusing materials, developing technologies capable of substituting high-impact inputs, such as petroleum products, and by reducing the distances the materials are transported," says the researcher.

Research centers in the USA and Europe have dedicated themselves to the study of biobinders, chemical products from renewable sources capable of replacing petroleum asphalt as the aggregate binding agent in the surface layer of paving. The research is still in the early stages.

With support from FAPESP, Savasini coordinates research focused on sustainability in asphalt paving, which includes the development of a biobinder as a possible alternative to petroleum asphalt being one of the aims. The project team has been investigating different biomasses found in the country.

A few years ago, the Paving Technology Laboratory at POLI-USP took part in research re-

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A pothole: lack of preventative maintenance is one of the causes of bad urban paving in the country

PHOTOS 1 VALE **2** LÉO RAMOS CHAVES / PESQUISA FAPESP MAGAZINE **INFOGRAPHIC** RODRIGO CUNHA

LOW-QUALITY PAVING

A study by the Brazilian National Confederation of Transport points out flaws in the Brazilian highway network

The 2021 Highways Study by the Brazilian National Confederation of Transport (CNT) evaluated the conditions of 109,100 kilometers of Brazilian highways and disapproved of the general state of 61.8% of the studied road network. The characteristics studied are the paving, signposting, and geometry of the road. The work, conducted by the CNT, identified the existence of some type of problem with paving for 57,000 km, slightly over half the total. The asphalt covering was classified as bad for 17,300 km and terrible for 6,300 km.

According to civil engineer Liedi Légi Bariani Bernucci, director of the São Paulo State Institute for Technological Research (IPT) and former coordinator of the Paving Technology Laboratory (LTP) at the Polytechnic School of the University of São Paulo (POLI-USP), the highways in Brazil presented a lower quality than those verified in Europe and the USA, but not because of the asphalt used, which has equivalent technical characteristics to that found abroad. "Our biggest problems are the lower lifespan of the paving normally stipulated in the project, the lack of technological resources of some executors, and the inadequate inspection of work preparation," she says.

Among the causes of paving defects, the CNT identified the lack of both preventative maintenance and inspection of vehicles traveling on roads with excess weight. The problems occur more frequently on public highways. The CNT Highway Study disapproved of the general state of 72% of the sections of highway under public management and 26% of those under private concession.

In urban centers, the quality of asphalt paving is also affected by the disorganized intervention of water, sewage, gas, and other concessionary services that carry out work beneath roads and avenues. Pothole resurfacing compromises the integrity of the asphalt layer, often resulting in cracks and splits where rainwater penetrates, causing ruptures and new potholes.

garding a biobinder obtained from an imported byproduct of pine wood, capable of replacing traditional asphalt. The biobinder was developed with Greca Asfaltos and Quimigel from Paraná and São Paulo, respectively, companies specializing in asphalt additives. The new product was tested in 2017 on BR-050, which connects Brasília to Santos, São Paulo State. The results were published in the magazine *Construction and Building Materials* in 2021.

"The efficiency of the biobinder is proven, but its production is not economically viable in Brazil," laments Wander Omena, Research and Development manager at Greca. The production of the biobinder tested in 2017, he explains, depends on a substance obtained from processing black liquor, a byproduct from the cellulose industry, in a biorefinery. "We do not have a biorefinery for this in Brazil, and the cost of importing the input is prohibitive," he says.

Greca was responsible for introducing rubberized asphalt to the country 21 years ago; this asphalt is made with rubber dust from tires. The innovation originated in the USA, but the asphalt used there contains up to 10% rubber, whereas the Brazilian version uses 15% rubber. Another national innovation is the addition of additives to stabilize the viscosity of the material. The rubber increases the durability of the asphalt, and according to a study by the Paving Laboratory at the Federal University of Rio Grande do Sul (UFRGS), the mixture is capable of decreasing crack propagation by 5.5 times, reducing the need for repair services.

Another advantage is the promotion of the circular economy in the tire industry. Every kilometer of seven-meter-wide paving with the mixture uses a thousand discarded tires. In 2021, Greca completed of 13,000 km of roads resurfaced with rubberized asphalt and 13 million reused tires. Added to the works of other rubberized asphalt suppliers, the total reaches 17,000 km of roads, which is still only a fraction, given the 221,000 km of paved highways in Brazil.

Rubberized asphalt is mainly used by private concessionaires. The Anchieta and Imigrantes highways in São Paulo State, which connect the state capital to the south coast, were completely resurfaced with rubberized asphalt, and the concessionaire EcoRodovias is using the material as a standard for resurfacing the highways it manages. The concessionaires CCR and Arteris also use the product.

The price of rubberized asphalt is approximately 15% higher than that of conventional asphalt, but it has greater durability. In Omena's opinion, the main obstacle to the material being more widely used in public works is the lack of technical knowledge of most contractors. Abroad, the Brazilian rubberized asphalt formula has already been regulated in China and is being evaluated for use in European countries. ■

The research projects and scientific articles consulted for this feature are listed in the online version.