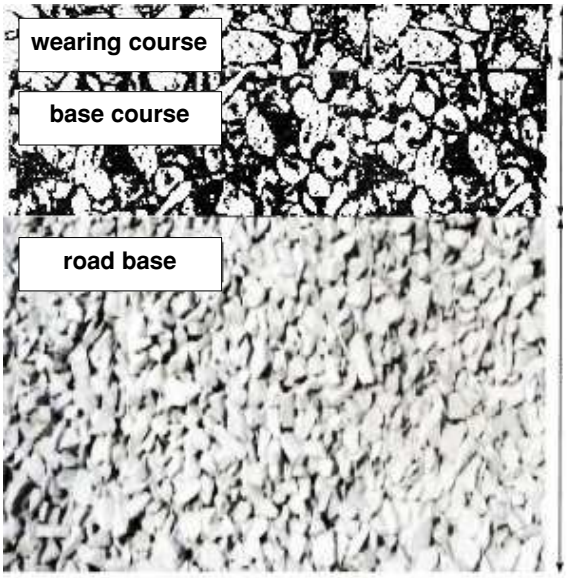
Roadstone - which rock?
Investigating the best rock type for the wearing course of roads

Roads are made of various types of rock aggregate (crushed rock fragments). Quarries provide the aggregate used in the construction of our roads. The rock type has to be carefully chosen so that it has suitable properties for the job it has to do.

Pupils are asked to work out which rocks are the most suitable for use as roadstone aggregate.
Show pupils the diagram of the cross section through a road surface (below) and provide them with copies of **Table 1** *(page 3)* and tell them that many rock types are suitable for the lower three layers providing they have sufficient strength and are packed in such a manner as to be permeable.
However, the top layer on which the traffic runs, **the wearing course**, takes much higher pressures and all the wear and tear of the traffic and of the weather. It is this wearing course which forms the main focus of this activity.

Cross section through a typical road surface

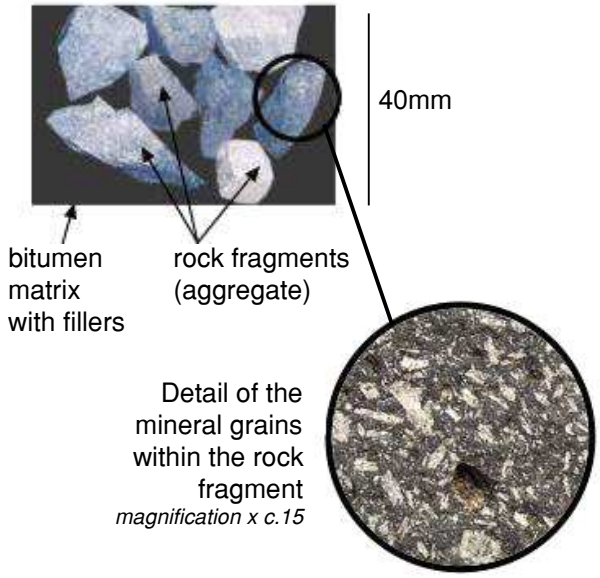


Thicknesses of these layers are typical values and depend on the amount of traffic the road has to take.
The rock aggregate and the bitumen matrix that hold it together are called ***asphalt***

Ask the pupils to suggest properties that the wearing course must have.
It must provide a durable, skid-resistant surface and must prevent water percolating down to the lower layers.
A much higher quality of rock is needed for this layer than for the other layers; only a few rock types are suitable, especially for motorways and other roads carrying much traffic.

Give the pupils copies of the **Pupil Information Sheet** *(page 4)*, **Table 3** *(page 5)* and, if possible, provide the samples listed. If required, also give them copies of **Tables 2a: Composition of rocks** and **Table 2b: Hardness of minerals and volcanic glass** *(page 3).* Without Tables 2a and 2b this is a good revision exercise.

The pupils should now complete Table 3 and decide which rocks are suitable for the wearing course of a road and which are not.



Cross section through the wearing layer of a road with a detail of a rock fragment

The back up

Title: Roadstone - which rock?

Subtitle: Investigating the best rock type for the wearing course of roads

Topic: This investigation can be carried out as a revision exercise of the major rock types in science, environmental science, geography or economics lessons.

Age range of pupils: 12 years and upwards

Time needed to complete activity: 30 minutes

Pupil learning outcomes: Pupils can:
- measure grain size of a selection of rocks;
- use six criteria to determine the best choice of rock for the wearing course of a road;
- appreciate that limestone is extensively used for the base course and road base because it is readily available. It is also used for the wearing course in areas where a lower specification is acceptable, such as car parks and private driveways.

Context:
Basalt, dolerite (and some other igneous rocks), and greywacke fulfil all six criteria and so are the best rocks to use for the wearing course, but their outcrops are not evenly distributed so transport costs are high. Rocks that are very poor are shale and oolitic limestone. Flint is very strong but would not be a good rock to use. It is made of one mineral and breaks into sharp angular pieces to which bitumen does not readily adhere.

Following up the activity:
Pupils could investigate local aggregate quarries to find out how the rock is used. It might be possible to arrange a visit.

Underlying principles:
- Rocks used for aggregate for the wearing course of the best quality roads must:-
  - have most minerals with hardness greater than 5 to resist abrasion
  - be made of two or more minerals with different hardnesses so that the surface does not become polished
  - be fine- or medium-grained
  - be well-cemented or made of interlocking crystals to resist pressures and stresses
  - have rough surfaces so that bitumen will adhere
  - not be porous. If water could get in then frost would cause it to shatter in winter.
- Economics often determines which rocks are used. If the transport costs are too high for the best quality rocks to be used, then inferior quality aggregate may be used instead, especially on minor roads.
- The best quality aggregate is used on motorways and on roads which bear a great deal of traffic.
- Although crystalline limestone is not the best rock for the wearing course, it is widely distributed across the country and is extensively used for the lower courses of roads of all types. In practice, one of the best rocks for the wearing course of major roads is a type of sandstone, known as greywacke, quarried at Ingleton in North Yorkshire and in mid-Wales, among other sites. Greywacke is composed of quartz and feldspar grains, with some clay matrix, cemented by iron oxides to form a tough rock. Its different components mean that it is worn away at different rates, so that it always maintains its skid resistant surface.
  Fine and medium-grained igneous rocks are extensively quarried from Charnwood Forest in Leicestershire. The central location in the country, and nearness to the motorway network, mean that the Charnwood roadstone features widely in English roads, in areas where other suitable rocks do not occur.

Thinking skill development:
By completing Table 3, the pupils are recognizing patterns. Discussion involves metacognition and looking at rocks that are unsuitable may cause cognitive conflict. Applying the relevant criteria to the sample rocks (or sample list) and working out which rocks are most suitable requires bridging skills.

Resource list:
- copies of Table 1, the Pupil Information Sheet and Table 3. Tables 2a and 2b are optional
- samples of the rocks listed in Table 3, if possible
- hand lenses or magnifying glasses if rock samples are available
- grain scale cards or rulers.

Useful links:
The design and construction of roads - http://community.dur.ac.uk/~des0www4/cal/roads/index.html
An idiot's guide to road maintenance - http://www.highwaysmaintenance.com/design.htm
A guide to aggregate testing - http://www.northstonematerials.com/filestore/documents/aggregate-tests.pdf
SoE unit Bulk Constructional Minerals, York e-library http://www.nationalstemcentre.org.uk/elibrary/resource/1147/bulk-constructional-minerals

Source:
Adapted from an original article by Dr. Mike Tuke, re-published by Peter and Maggie Williams in 'Blasts from the past 3: Roadstones', 'Teaching Earth Sciences', Vol 39, No.2 2014.
The Earthlearningidea Team is grateful to Clive Nicholas and Julian Smallshaw for their helpful advice in updating this activity. Julian Smallshaw is Head of Educational Development, The Institute of Quarrying.

TABLE 1 - ROAD LAYERS	
Name and thickness of layer	**Purpose and composition of layer**
Wearing course 13 - 38mm	Provides a skid- and wear-resistant surface for the traffic and protects the lower layers. Bitumen-bonded aggregate
Base course 38 - 76mm	Distributes the traffic loads on to the road base. Bitumen-bonded aggregate
Road base 102 - 204mm	Main load-bearing layer. Made of rocks with high crushing strength
Sub-base Variable	Builds surface up to approximately the correct level. Made of large fragments so that water cannot rise by capillary action

TABLE 2A: COMPOSITION OF ROCKS	
Igneous rocks	**Main minerals**
Andesite	feldspar, hornblende, augite
Basalt	feldspar, augite
Dolerite	feldspar, augite
Gabbro	feldspar, augite
Granite	feldspar, quartz, mica
Rhyolite	feldspar, quartz, mica, volcanic glass
Obsidian	volcanic glass
Pumice	volcanic glass
Metamorphic rocks	
Marble	calcite
Gneiss	quartz, feldspar, mica, hornblende
Quartzite	quartz
Schist	mica
Slate	mica
Sedimentary rocks	
Flint	quartz
Limestone	calcite
Sandstone	quartz
Greywacke	quartz, feldspar, clay minerals
Shale	clay minerals

TABLE 2B: HARDNESS OF MINERALS AND VOLCANIC GLASS	
Augite	6
Calcite	3
Clay minerals	2·5
Feldspar	6
Hornblende	6
Mica	2·5
Quartz	7
Volcanic glass	6

FROM QUARRY …..

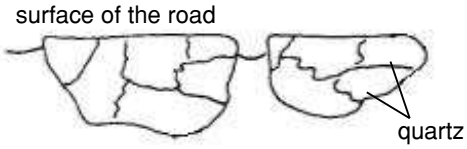
….. TO ROAD

Top photo: Bardon Hill Quarry, Leicestershire, Peter Williams
Bottom photo: Road mending in Sheffield, Peter Kennett

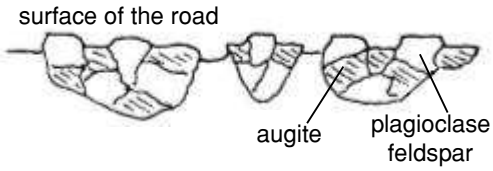
Roadstones - which rock? Pupil information sheet

Good roadstone for making the wearing course of roads must have the following properties:

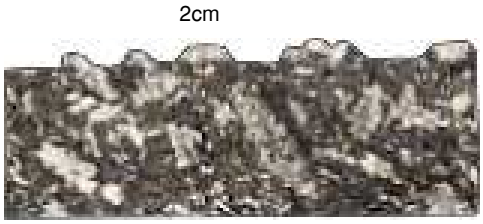
1. The majority of the minerals in the rocks must have a hardness greater than 5 so that the rock is able to resist the abrasion caused by the tyres of the vehicles.
2. The grains must wear in such a way that the exposed surface of the rock fragments (aggregate) does not become polished, otherwise the traffic would skid. This means that the rock must be made of two or more minerals with different hardnesses.



Mineral grains all the same i.e. in quartzite
Rock fragments made of only one mineral wear to a flat surface which does not prevent vehicle skidding



Several mineral grains e.g. dolerite
When rock fragments are made of several different mineral grains with different hardnesses, then the rock fragments wear to a stepped surface which is skid-resistant



Detail of crystal wear in a rock fragment

Worn road surface with aggregate raised above bitumen matrix
£1 coin for scale

Diagram and photograph by P. and M. Williams and reproduced with permission from 'Teaching Earth Sciences', Vol 39 No.2 2014

3. The rock needs to be fine- to medium-grained so that fragments 0.5cm in diameter contain grains of several different minerals.
4. The individual grains need to be strongly held together so that the aggregate does not crumble under the pressures and stresses exerted by the vehicles. This means the rock must be either well-cemented or made of interlocking crystals.
5. The aggregates must have rough surfaces so that the bitumen can adhere to them. Bitumen does not adhere well to glassy surfaces e.g. flint and obsidian, but it does adhere to most other rocks.
6. The rock of which the aggregate is made must not be porous otherwise freezing and thawing during the winter might shatter the rock.

Table 3: Geology of Roadstone

Examine each sample and for each:-

1. Measure its grain size (if it is too small to measure, put < 0.5mm)

2. Look up its mineral composition and list the minerals in the table below

3. Look up the hardness of each mineral and write it beside the mineral on the table

4. Complete the table by putting a tick where the rock satisfies the criteria 1 - 6 and a cross where it does not

Rock	Grain size	Minerals with hardness of each	1	2	3	4	5	6
Granite								
Gabbro								
Dolerite								
Basalt (not vesicular or amygdaloidal)								
Quartz sandstone, poorly cemented								
Greywacke, well cemented								
Shale								
Oolitic limestone								
Flint								
Quartzite								
Schist								
Slate								

Which are the best three rocks for making the wearing course of a major road?

1. most minerals with hardness > 5
2. two or more minerals
3. grain size < 2mm
4. strong rock
5. bitumen adheres well
6. low porosity