Screenings from the Soil Research Lab

IOWA ENGINEERING EXPERIMENT STATION
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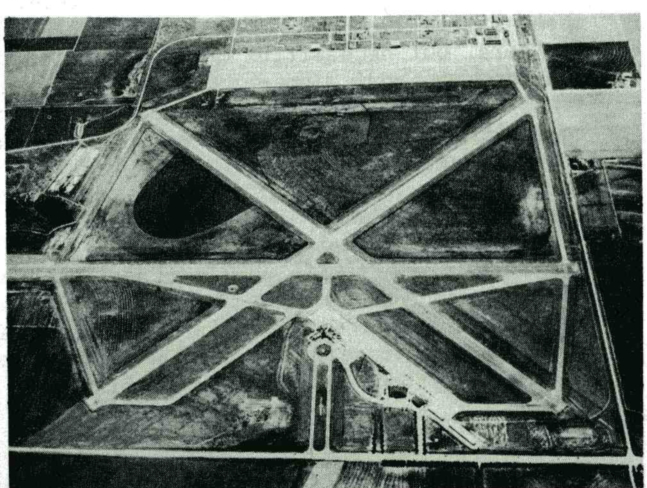
SAGA OF SOIL-CEMENT

Days of the Deal

Back in the good old days when they still spelled Depression with a D and lined up for bread instead of unemployment benefits, the whole world recognized the salesman of portland cement because he had the stuff running out of his ears. And this before the government had learned about subsidizing to increase overproduction.

One fateful day cement peddler Archimedes Beowulf in a sudden burst of zeal sprinkled cement on his breakfast food. Breakfast was crunchier than usual that morning. Beowulf also used portland cement to fertilize the tulips, and his wife complained he was turning the back yard into a rock garden. He patiently observed, "Quite so, nothing can grow, but at least there are no weeds."

One thing led to another, and great inventions from little inspirations come, otherwise who ever could have invented Kleenex? Our hero resolved to make the whole world his rock garden. Unfortunately his wife still preferred tulips. "All right, I shall build roads," he countered. And he did. The End. This is a true story except for slight deviations to protect the distorted outlook. Necessity is the Mother of Invention; the only question is who the hell ever thought of necessity.

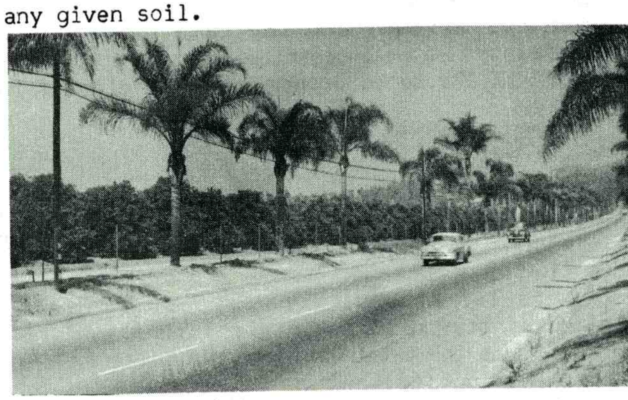


Soil-cement airfield in Texas, U.S.A.

Scientific Version

A first try is like kindergarten art; the impulse is there, but in the end a horse may look like mother, or vice versa. Actually soil-cement was first tried in the 1920's by state highway departments in Iowa, South Dakota, Ohio, California, and another state that slips the mind--oh, yes, Texas. The necessary dose of exactitude didn't come until 1929 when R. R. Proctor devised the test that would revolutionize soil compaction and spell doom to guesswork. Now one rams soil into a mold, weighs it and predicts field density and finds the optimum moisture content.

In 1932-34 the South Carolina Highway Department built several test sections of road and further showed that soil-cement was feasible. The Portland Cement Association gasped with pleasure and inaugurated what is now considered the classic research program in soil stabilization. The major conclusion was that durability was the most important criteria in design, and tests were devised to show how much cement was needed to stabilize any given soil.



Gorgeous soil-cement highway in California. On the surface it looks like black-top. On the surface it _is_ black-top. (Got to protect that soil-cement.)

The Johnsonville Pavement

The first scientifically controlled field test of soil-cement was in 1935, when a $1\frac{1}{2}$ mile section of State Route 41 near Johnsonville, South Carolina, was stabilized. Mixing was done the only way anybody knew how, with farm equipment and blade graders. Yes, and the road stood up. In fact, it's still standing up, a rather sensational record for an experimental project with a new material.

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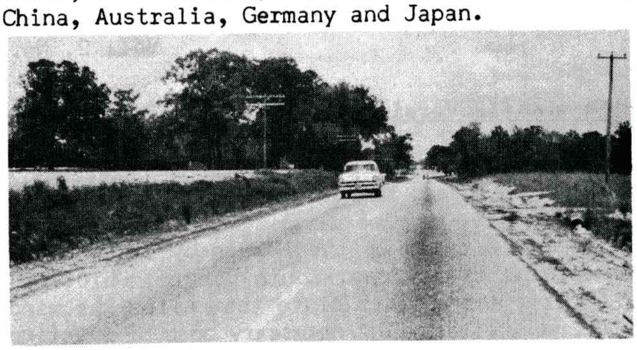
By 1937 thirteen states had put in experimental soil-cement roads and the boom was on. Research results were disseminated through papers presented to the Highway Research Board, and in 1940 the Portland Cement Association began publication of the Soil-Cement News. In the meantime soil-cement was going international; jobs were built in France, England, the Netherlands, South Africa, Brazil, Argentina, Canada, China, Australia, Germany and Japan.

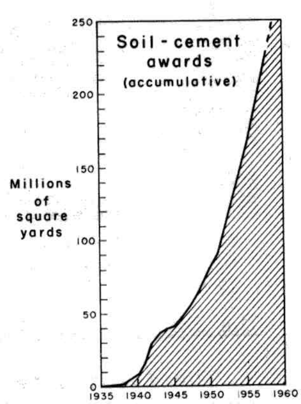


The original Johnsonville, S.C. soil-cement pavement constructed in 1935. Cores taken a month after construction tested at 480 psi, whereas cores cut 20 years later broke at 922 psi. Such long-term strength gains are characteristic of soil-cement.

Coming in on a Wing and a Soil-Cement Landing Strip

About 1940 soil-cement went to war and turned in a creditable job. For both sides. The main use was for airfields, which had to be built quickly and with a minimum of imported materials. Germany put in 120 million sq yd, equivalent to about 10,000 miles of 20 foot roadway. The U. S. put in about 25 million sq yd. New special machines replaced the farm implements formerly used for mixing, and the rate of production soared until a well organized team could construct 5,000-10,000 sq yd or upwards of a mile of road a day.

Peace Effort



After the war soil-cement marched home, joined a veterans' organization and quickly outgrew its uniform. In five years the total U.S. yardage doubled, and in five more years it doubled again! And it's still doubling. By June, 1958, 230 million sq yd of soil-cement had been awarded or constructed in the U. S. This is equivalent to about 20,000 miles of 20-ft pavement, or once around the earth not quite. Only a slight extrapolation is necessary to show that in 75 years the entire country will be soil-cement and you will be able to drive anywhere except Lake Michigan without getting stuck. Another 25 years should do the entire earth so it will look like an oblate billiard ball. If you don't believe this you have an insecure grasp of higher mathematics.

A major emotional snag for soil-cement roads is that their beauty must be forever obscured by a black, noxious film called asphalt. Soil-cement base courses need a bituminous wearing surface. Despite parental objections the marriage has come off rather well, except that on the surface the offspring looks too much like asphalt and too little like soil-cement. Maybe both sides want the credit and neither wants the blame.

HEY MAN, WHAT IS IT?

If you're not in the know you may not dig this crazy stuff. Therefore we shall explain. Soil-cement is a mixture of soil plus cement, but instead of pouring it like concrete it is moistened and compacted like--well, like soil-cement. Then in a few days it gets hard. Strength is adequate but not so high as in concrete. The price is not so high either.

Concrete people will be happy to know that soil-cement is currently recommended only for light traffic roads, runways or parking lots or for impervious ditch, canal, or reservoir linings. In roads, runways or lots it constitutes a base course which otherwise would be constructed of granular material such as crushed stone. California now specifies soil-cement as a subbase under all main route concrete highways.

HOUR OF DECISION: HOW MUCH WILL IT COST?

One fact is brutally clear: a pocketbook opens rather easily to buy a bit of fluff and feathers, but necessities must be haggled over and purchased with a scowl. How sad that autos, TV sets, college degrees, and other once-glamorous commodities have now crossed over into the catalogue of humble necessities. Cuts down on their retail value. In fact, it's questionable whether college profs should want to be thought of as being really necessary; it might lob them into the same lifeboat with public school teachers. Better to maintain an air of prestige, glamour, and overall worthlessness, like a football coach. Might as well trade on the foibles of the public rather than stand by for the crucifixion.

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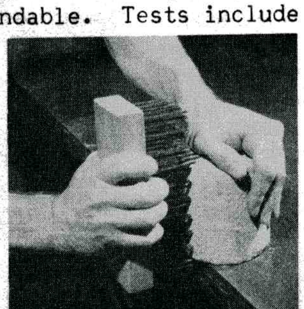
Roads, unfortunately, have long been thought of as necessary, and there is seldom a semblance of glamour or romance except in an Alaska Highway or some spectacular pretzeline tunneliferous interchange that's fun to drive over. In other words, roads should cost as little per year as possible. This opens the door for soil-cement, which is often cheaper than other modes of construction and is now known to last at least as long as 20 years, and probably longer. The next question is how much cement do we have to put in the road? It depends on the soil. Got to have tests.

Soil-cement parking lot, Minneapolis, Minnesota. Room for 7000 cars.

Tests, Part I. That They Be Dependable...

Quite an array of question marks faced the P.C.A. in the 1930's when it decided to establish tests for minimum cement requirements. Much of this pioneer work was done by Miles D. Catton, who saw to it that thousands of specimens were molded with different soils and different cement contents. The specimens were cured and tested and set outdoors in the cold, cruel world near Chicago, Illinois. There they either stand or fall apart from the merciless pounding of the elements, hydrogen, oxygen, nitrogen, carbon, etc. Many specimens are still there, vainly trying to fall apart and be done with this old world. Longevity overlooks discomfort.

Eventually tests and criteria were set up, and experience has shown them to be adequate, accurate, and highly commendable. Tests include two types of treatment: wetting and drying, and freezing and thawing. Wire brushing was added between cycles to remove loose material. Whether a mix passes or not is decided by the weight loss after 12 cycles.



Tests, Part II. Prime Ribs and Short Cuts

Laziness on the part of an engineer is a matter of sincere self denial, since everybody knows that hard work makes the body strong and benefits the liver. Soil-cement durability tests cause undue bodily exercise when one's natural inclination is to sit around and loaf. An easier way is needed.

Compressive strength is now the standby in jolly old England, where the American durability tests are regarded as a bit on the harsh side. A seven-day strength of 250 psi is the magic number for acceptance, with a minimum of 400 to 500 psi recommended for more severe climates or uses.

In the United States, unconfined compressive strength has been regarded with caution because of our more rigorous climate, and it wasn't until 1953 that J. A. Leadabrand and L. T. Norling of the P.C.A. came up with some helpful answers. From tests on 2,229 sandy soils they devised a short-cut procedure which relates cement requirements to grain size, compacted density, and compressive strength. Since soil-cement often utilizes sandy or gravelly soils this makes for a monumental saving in time and effort. Results are published in Highway Research Board Bulletin 69. No shortcut test has yet been developed for silty and clayey soils, but more research should give an answer.

BIG SHORTCUT: THE SOIL SERIOUS

Ordinarily we avoid discussions of religion, but it seems pertinent to mention the First Church of Soil Science and followers of the prophet Glinka and his various apostles and archangels, the most famous being Marbut.

Somewhere in this shadowy realm lurks the Soil Surveyor, his head bowed and eyes focussed downward to get a better look at Heaven. Symbols of his order are the auger and spade, plus that holy look. The soil surveyor maps soils, ostensibly to show how well they grow wheat or corn but actually because his eager mind is fasinated by the pretty colors and layers. The result of his efforts is the Agricultural Soil Map, also in colors. Fortunately for engineers the soil map is drawn on scientific principles, not on how much wheat or corn. We therefore find it useful. The latest scheme is to try to relate cement requirement to the basic soil map unit, the soil series.

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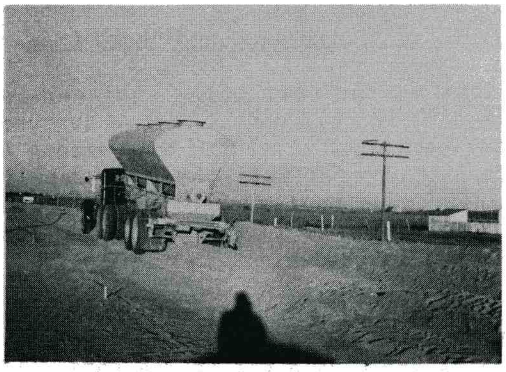
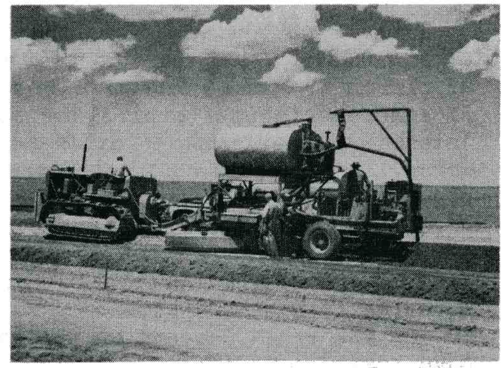
SOIL-CEMENT CONSTRUCTION PROCEDURES



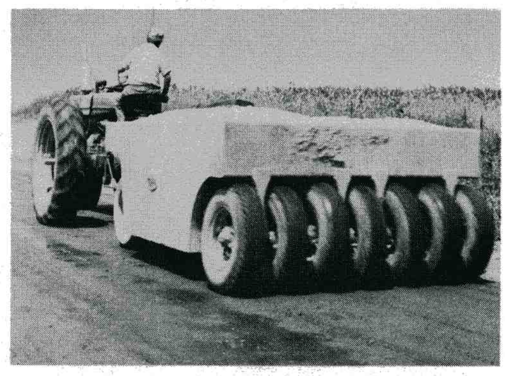
Construction begins with doling out of cement.

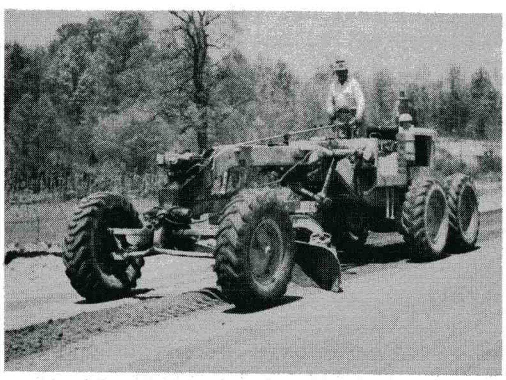
Mixing is done with special machines. This machine adds water, mixes, and leaves the soil in a windrow.



Compaction begins. Sheepfoot roller feet penetrate loose soil and compact the base from the bottom up. Usual compacted base thickness is 6 or 8".

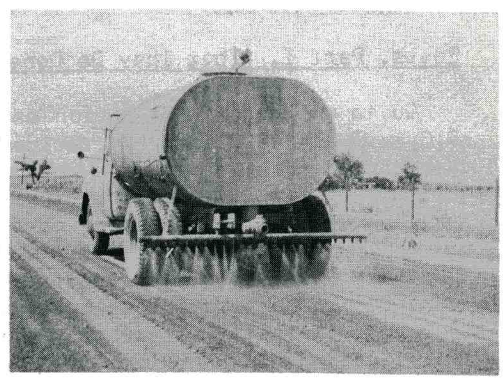
A rubber-tired roller compacts the surface layer.

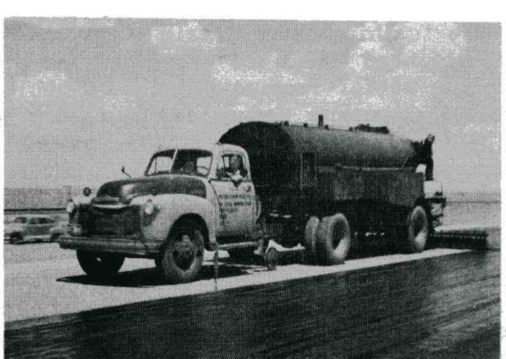




The compacted road-base is accurately trimmed to grade

and occasionally sprinkled to prevent drying.





Asphaltic prime coat and wearing surface finish up the paving. Soil-cement offers a cheap conversion for existing gravel roads, which usually require a low percent cement.

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The Soil Profile

Anyone who has ever dug a ditch or played around a post hole knows that the color and texture of soil differ as one digs down. These differences show up as layers called horizons. In keeping with the educational level of the ditch digger the horizons are designated by A, B, and C.

The A horizon is the brown or black, organic, loamy material the layman calls topsoil. (In forested regions the A horizon sometimes includes a light, ash-like layer or A_2.) Underneath the A is the B horizon, often clayey because of accumulation of weathered materials derived from the overlying A. In lay terminology the B horizon is the subsoil. The C horizon is the unconsolidated parent material, which was the start of it all. It is either unweathered sediment such as glacial till, or weathered and disintegrated bedrock. The A and B horizons together constitute the solum, a precious bit of Latin meaning soil.

Zones, Intrazones, and Azones

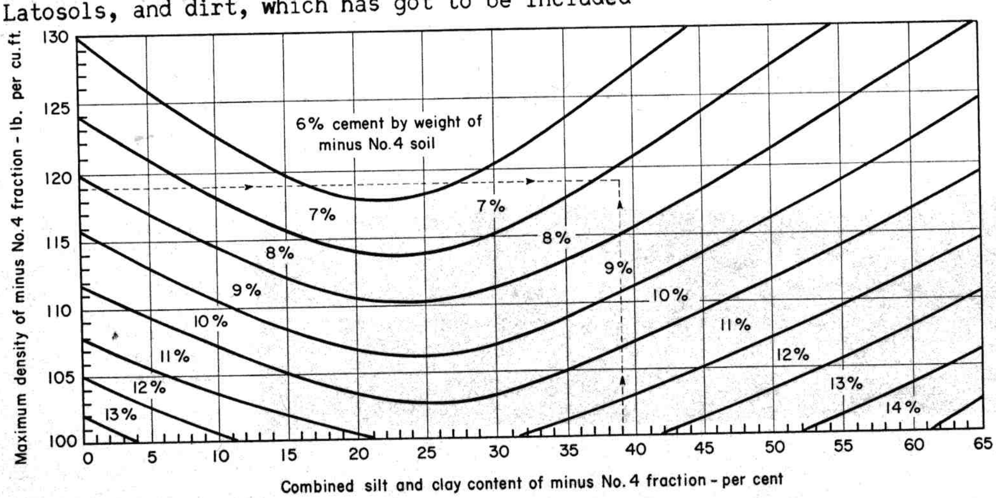
The variables affecting the soil profile are five toes that support the foot: climate, organisms, topography, parent material and time. Theoretically a change in any one factor will give a different kind of soil.

A scientists' first instinct is to classify, whether his subject is personality quirks of the dung beetle or how to bet on a horse. Classification of soils follows a biological scheme, decreasing from order through group, family, and series. The three orders are first of all zonal soils, whose character mainly reflect climatic zone. Zonal soils include such great soil groups as Podzols, Chernozems, Chestnuts, Brunizems, Latosols, and dirt, which has got to be included somewhere. Intrazonal soils are affected more by local saline or boggy conditions and include such classics as Wiesenboden, Planosol, Brown Forest, etc. Azonal soils reflect mainly parent material and are more a problem in geology. Each great soil group includes a large number of series to reflect the lesser variables which still like to vary: For example, all Podzols are similar but not identical; differences which depend on parent material, topography, etc., are reflected in soil family and series.

A loessial soil profile with A, B, and C horizons being sampled for tests with soil-cement. Biological activity ordinarily centers in the A.

GREAT PAINS STATES

The reason for mentioning all this is that cement requirement does relate to soil series and to a lesser extent to great soil group. Proof came in studies of 43 series in various Great Plains states and Washington and Idaho. Cement requirement not only relates closely to horizon and series, but it is consistent! Now we say poof! to lab testing; just give us the soil series, available from soil survey reports of the U. S. Department of Agriculture. Cement requirement--soil series correlations are described by Leadabrand, Norling and Hurless in Highway Research Board Bulletin 148, 1957.



One of several graphs giving a short-cut to cement requirement for sandy soils. Cement content is read directly and checked by compressive strength.

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Sadness in the Silt Loams

Correlations, like politicians, sometimes have their off-years. Sampling locations in Iowa were intentionally chosen to give variations within each soil series, not an average or modal series profile. This sharpens the stab. Result? Coarse-textured loess in the high western Iowa bluffs mapped in the Hamburg series has an almost uniform cement requirement of 12%. Unfortunately right next door the Ida and Monona series also on loess require up to 20% cement. Farther east, where the loess has more clay and more soil profile, the Marshall series requires 18% for the A horizon and 16% for the B and C. In eastern Iowa the correlations are much worse, partly because of the variability of the series. Fayette in one area requires 15% cement, in another 23%. Actually this is not so much correlation trouble as an extraordinary unnatural appetite for cement.

Reasons

Back to the lab, Sir Galahad. The answer was abnormal freeze-thaw destruction by scaling. Why? One looks at the specimens. One sees ice. Obvious.

During freezing, the water in soils moves towards the cold zone by a process called thermal osmosis. Put soil-cement specimens in the deep freeze, water tends to move out from the middle and saturate the surface layer. Here it freezes, expands, and causes the surface layer to spall off. Next cycle, new surface, new spall. Repeat, repeat, repeat. Finally no specimen left. How now?

This beautiful bit of theory does not hold for coarse loess because the pores are too large for easy ice plugging and building up of pressure. Conversely in high-clay loess the water movement and spalling are reduced by lower permeability. It is only the middle area that is critical.

Continue?

Unshaken by grimness, our hearty researchers blink off a tear or two and continue the march. One possibility to reduce freeze-thaw loss from spalling is to add a little sand. This should be looked into. Meantime the series correlation work continues with other Iowa soils, and results are practically guaranteed to be at least as good as for the loess. Possibilities for reduction in cement requirement are also under study. For example, can we cut requirement by adding a little lime or fly ash? And then there are trace chemicals like acetyl-salicytic acid, which has great promise as a pain reliever. Research goes on.

REFERENCES SIGHTED

Ample literature and manuals on soil-cement are published by the Portland Cement Association, 33 West Grand Avenue, Chicago 10, Illinois. The Soil-Cement Laboratory Handbook and Soil-Cement Construction Handbook are must-have items. Future pedologists should have the Soil Survey Manual, Handbook 18 of the U.S.D.A. Data on Iowa loess are in "Cement Requirements to Stabilize Eastern and Western Iowa Loesses," by R. L. Handy and D. T. Davidson, Ia. Acad. Sci. Proc. 64:274-313, 1957.

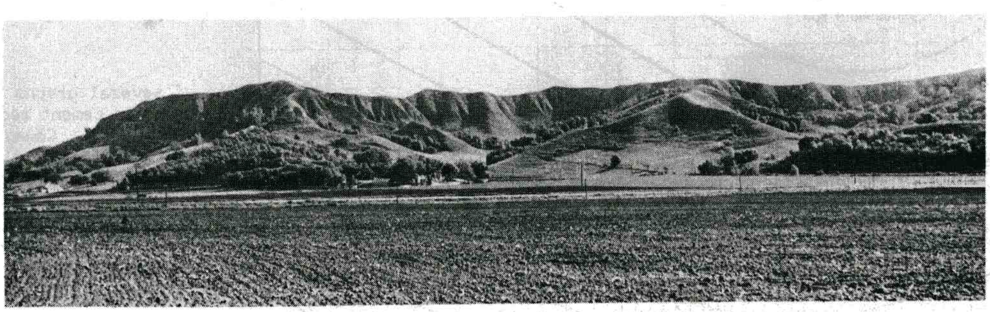
ACKNOWLEDGEMENTS

Research on soil series cement requirements is a joint program of the Iowa Engineering Experiment Station and the P.C.A. Iowa soil stabilization research is carried on under projects sponsored by the Iowa Highway Research Board with funds from the Iowa State Highway Commission.

Finally, a joyous hug to Geotimes and Robert Bates for a kind and clever write-up on Screenings. We're really not that good, you know....

RLH

IN THE NEXT ISSUE: X rays, for the analysis of soils?



High bluffs in western Iowa. About the top half of the hills is loess, mostly Hamburg series which is azonal--no soil profile because of dryness and rapid natural erosion. This loess can be stabilized with 12% cement.

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