ECONOCRETE IN PAVEMENT DESIGN

W. A. Yrjanson
Director of Engineering
American Concrete Paving Association

In many areas of the United States, the supply of conventional aggregates meeting present specifications is rapidly being depleted or has already become exhausted. This shortage to some extent is due to restrictive specifications and to a lack of technology and development to utilize those aggregates in a concrete pavement system. With the necessary advances in research and development, previously rejected aggregate sources may furnish a substantial amount of the aggregates needed in pavement construction in some areas of the country. Utilization of such aggregates does not only alleviate an existing problem of aggregate supply but also represents economic and ecological advantages.

With the thought in mind of better utilization of these materials, the American Concrete Paving Association's Technical Subcommittee on Materials and Mix Design started work in 1973 on the development of a composite concrete pavement structure. The objective was to produce a high quality, skid resistant, durable concrete surfacing on top of a concrete designed for local environmental conditions and made from local commercially available materials. The bottom layer of the two-course slab was intended to make use of crusher-run or other locally available aggregates and a cement factor needed to develop the strength and durability for the intended use. The surface course would be a high quality concrete making use of aggregates having superior resistance to wear and weathering and providing good skid resistance.

The term "Econocrete" was coined to describe the concrete mixtures developed under this program. Econocrete is portland cement concrete designed for a specific application and environment and, in general, making use of local commercially produced aggregates. These aggregates do not necessarily meet conventional quality standards for aggregates used in pavements.

AGGREGATES FOR ECONOCRETE

"Highway consumption of sand, gravel, and crushed stone is nearing 1 billion tons per year and is expected to increase to about 1.5 billion tons annually by 1985. Total production for all uses will probably reach 4 billion tons annually by that time." This quote was taken from NCHRP Report 100 entitled "Research Needs Relating to Performance of Aggregates in Highway Construction."

As the demand for aggregates continues to increase in all parts of the country, more geographic areas will experience depletion of conventional aggregate sources. Therefore, ways must be found to utilize more locally available aggregates, not necessarily meeting conventional specifications, in a pavement structural system. Restrictive specification requirements will have to be reviewed to determine their suitability, particularly in areas experiencing aggregate shortages.

These restrictive requirements were placed in some cases because of the performance characteristics of the aggregates when exposed at the pavement surface. These undesirable aggregate characteristics may be manifested in such conditions as a slippery pave-

ment, lack of abrasion resistance, an undesirable amount of popouts, etc. This type of aggregate can be used in the econocrete concept for the lower course in a composite pavement structure. Aggregate sources meeting conventional quality standards are used with such modifications as using a unit aggregate, gradation changes, proportioning, etc.

In areas where crushed stone is the major source of coarse aggregate and sand is not locally available, a crushed stone with a base course type of gradation could be used for the lower course in a composite pavement with an imported sand or stone used in the topping mix. With proper attention to environmental and service requirements, mix designs could be developed using this type material in full-depth paving for such applications as parking lots, streets, low traffic roads, and shoulder concrete.

The initial test program in Florida included four different aggregates, some unique to that state. These aggregates are not presently permitted for use as an aggregate for concrete paving. The aggregates tested included Ocala limerock, a low calcium oolite, coquina, a stabilizing grade of limerock, and sand shell material. Iowa's initial test program included 27 different aggregate sources including both sand and gravel and crushed stone located throughout the state. Many of the sources did not meet current specifications for concrete aggregate.

Other examples of aggregates not presently permitted in pavements but which would be used in a concrete structural system are: some manufactured limestone sand or coarse aggregates which polish under traffic; gravels with an excessive amount of deleterious materials which cause popouts; high sand content mixes; sand shell aggregates; and aggregates with low abrasion resistance. Of course conventional concrete aggregates can be used for any of the applications covered in this paper with mix designs appropriate for the intended use of the material.

The initial test program was conducted in cooperation with the state highway department laboratories from Georgia, South Carolina, and Florida. Mix designs were developed using crusher-run material from sources that met conventional quality standards for concrete aggregate and also from sources that did not meet these standards.

A typical gradation of the crusher-run material is shown in Figure 1. You will note that 100 percent passed the 1 1/2-inch sieve with 37 percent passing the No. 4 sieve and 5.1 percent passing the 200 sieve. This aggregate had a higher percentage of fines (-200 mesh material) than aggregates normally used for concrete pavements. For the aggregates used in the preliminary test program, the -200 fraction in the aggregates was in the range of 12 to 14 percent of the minus No. 4 portion of the aggregate or what would normally be classed as the fine aggregate (sand) portion of the aggregates. With the low cement factors used in the initial tests, 300 pounds per cubic yard, these extra fines along with the entrained air and the water reducing admixture were a big help in providing a cohesive, workable mix suitable for slipform paving.

Figures 2 and 3 illustrate the strength and elastic modulus values of a unit aggregate from a crushed limestone graded as shown in Figure 4. This limestone meets the conventional quality standards for concrete aggregate except for gradation. Figure 5 is a nomograph of the elastic modulus values of a relatively soft Ocala limerock from Florida. The wide range of physical properties of the concrete made from these and other types of aggregates makes it mandatory that the physical properties of concrete made from the various materials be determined in order to properly design composite pavement structures and other structural elements in a concrete pavement system.

USES

The subcommittee felt that in addition to use in a composite pavement structure, this

type of concrete could be designed for use on concrete shoulders, concrete subbases, or concrete for municipal paving. The quality demands for this type of concrete will vary from one part of the country to another depending upon local environmental conditions and how the material is used -- composite pavements, shoulders, subbases, streets, etc. Since the quality demands vary by geographic area and use, mix designs were developed in all regions using materials locally available.

Composite Pavements

Figure 6 illustrates the use of econocrete in a composite pavement structure. For this type of application, the topping and base concrete are cast monolithically in a procedure similar to that used in two-course mesh pavement construction with some modifications. Bonding of the layers will result in the most efficient use of materials since this will create the strongest pavement structure for a composite design. The econocrete course in this type of design can be made in many cases with aggregates not presently being used for pavement construction as discussed earlier.

The use of a composite concrete pavement is not new to the United States or European countries. The earliest concrete pavements built in this country were of composite design. Figure 7 illustrates that composite pavements have served under some very severe climatic conditions in the United States. The core sample on the right is from the first concrete street built in the U. S. on Court Avenue in Bellefontaine, Ohio. The pavement, built in 1893, was of two-course construction using two different aggregates in the upper and lower courses and a cement content that was higher in the top course. The sample on the left is a section of a core from North Dakota's first concrete pavement. This pavement was built on Fifth Street in Grand Forks in 1910. The base is a local gravel covered by a topping mix containing crushed granite. During a rededication ceremony in 1962, Court Avenue in Bellefontaine had entered its 70th year of continuous service and had carried a variety of traffic that virtually reflects the history of U. S. road transportation. Many of the earliest concrete streets built in this country were of composite design and provided many years of service without major maintenance.

Very few composite concrete pavements have been built in the U. S. during the last 50 years. There are a few exceptions as shown in Figure 8 which illustrates a composite pavement structure built in the early 1960's within the urban limits of Houston, Texas, on the right frontage road of U. S. 59 between Weslayson Drive and Buffalo Speedway. The design consists of a three-inch lightweight concrete placed monolithically with a four-inch shell aggregate concrete. The pavement is continuously reinforced using 0.3 percent longitudinal steel and is placed on a 6-inch cement stabilized sand shell base. Both the lightweight and shell aggregate concrete have a low modulus of elasticity. In a recent inspection by Federal Highway Administration personnel, it was reported that the pavement is in excellent condition and is carrying fairly heavy traffic. The cracks in the continuously reinforced pavement are very tight with practically no spalling and are spaced about 10 to 14 feet apart.

Subbases

During the test program it became evident that a properly designed mix containing 200 to 250 pounds of cement per cubic yard would be suitable as a subbase for concrete pavements. Because of the low cement factor in the mixes, air entrainment is required in most materials to obtain a plastic, workable mix. Water reducers have also been used to advantage.

Figure 9 illustrates the use of econocrete as a subbase for conventional concrete pavements which will be subjected to high volumes and weights of traffic. An econocrete sub-

base would provide a very durable, erosion resistant surface which would inhibit any tendency for joint faulting caused by erosion of the subbase surface for these high volume traffic pavements. When placed with modern equipment, very close surface tolerances can be maintained which will contribute to building a smoother pavement and also cut contractor yield losses to a minimum while still maintaining adequate pavement depth.

An econocrete subbase will also permit the paving contractor to utilize his own mixing and placing equipment for the subbase, thus spreading his move-in costs over a greater volume of work. The scheduling of the paving contractor's work would be more definite than when a subbase of a different type is sublet to another contractor. In many cases the work schedule maintained by the base subcontractor does not mesh with the paving contractor's schedule, and delays can result. The finish tolerances being obtained on some stabilized subbases have resulted in excessive concrete overruns in order to meet minimum pavement core depth requirements. These problems can be minimized with an econocrete subbase, plus an econocrete subbase will add considerably to the load carrying capacity of a concrete pavement structure.

Over 3 million square yards of econocrete type subbases have been built in the past few years on highway and airport projects. Slipform construction of this type base is shown in Figures 10 and 11.

Concrete Shoulders

Figure 12 illustrates the use of econocrete for shoulders adjacent to concrete pavements. This type of construction could be used on new pavements or for rebuilding shoulders on existing pavements. The requirements for shoulder concrete are not as demanding as the main roadway pavement. Normally shoulders receive very little traffic, and the abrasion resistance and strength requirements are lower. Econocrete mixes can be designed to meet the requirements for the strength and durability needed in different sections of the country. Concrete shoulders provide several safety features needed in modern, heavily traveled roadways. Rumble strips formed in the plastic concrete provide audible warning to motorists straying from the traffic lanes, and they also provide visible delineation of shoulder areas. Concrete shoulders improve mainline pavement performance by providing positive means of maintaining a tight joint between the pavement and shoulder which minimizes water infiltration along this joint which is the major point of water entry under a concrete pavement. A tied shoulder-pavement joint will also reduce deflections at the pavement edge which will improve mainline pavement performance.

Street Paving

Figure 13 illustrates another large potential use for econocrete for construction of street pavements. In the case of low volume traffic streets such as residential or residential collector streets or parking lots, econocrete could be designed for use for the full depth of the pavement structure. Where higher traffic volumes would dictate a higher abrasion, a topping mix or a higher strength econocrete could be used. Where aggregates are subjected to polishing resulting in a reduction in skid resistance on high volume streets, a topping mix could also be used.

SUMMARY

The Federal Highway Administration has endorsed the econocrete concept of pavement construction and issued a notice covering its use in Federal Aid projects. The notice covers both non-experimental and experimental uses of econocrete.

The econocrete concept will provide engineers with another design option which could prove to be the most economical in several geographic areas of the United States. It will also provide a means of utilizing more local aggregates in a concrete pavement structure with the resultant savings in energy through reduced hauling costs.

SIEVE SIZE	SOURCE 1 – GEORGIA CRUSHED QUARTZITE PERCENT PASSING
1 1/2"	100
1"	92
3/4"	80
1/2"	64
3/8"	54
No. 4	37
No. 8	30
No. 16	23
No. 30	16
No. 50	10
No. 100	6
No. 200	5.1

Figure 1

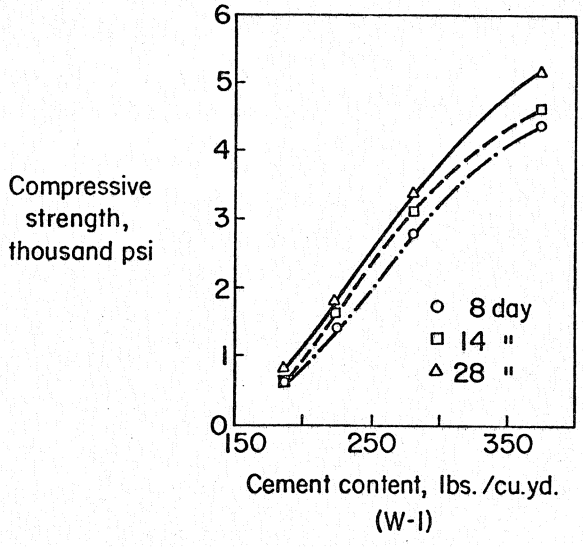


Figure 2

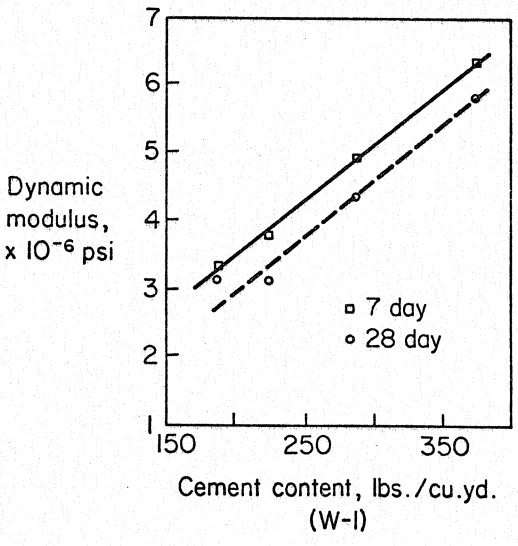
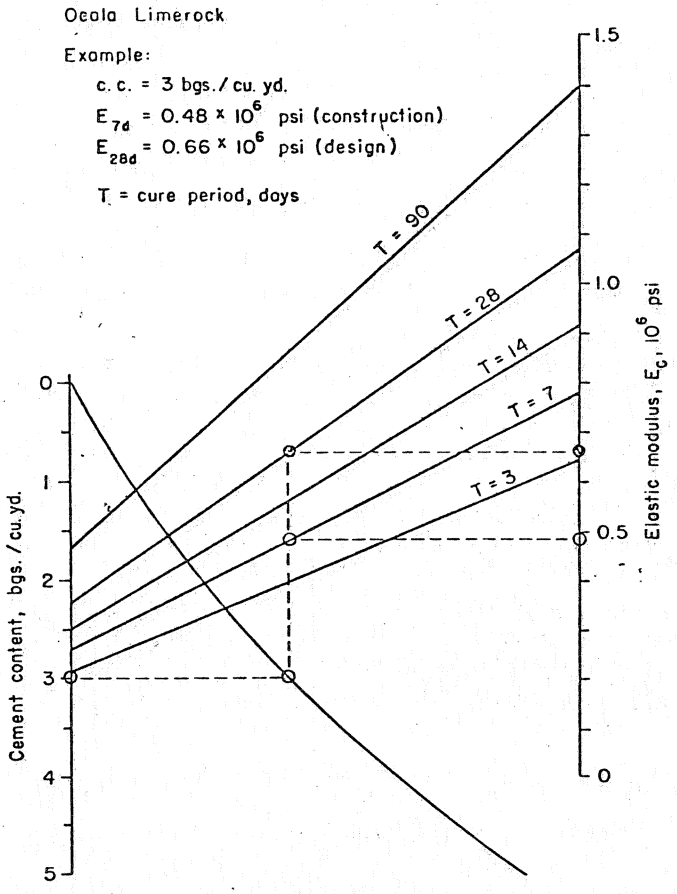


Figure 3

Gradation of Crushed Limestone Unit Aggregate Used in Econocrete Trial Batches (W-1)

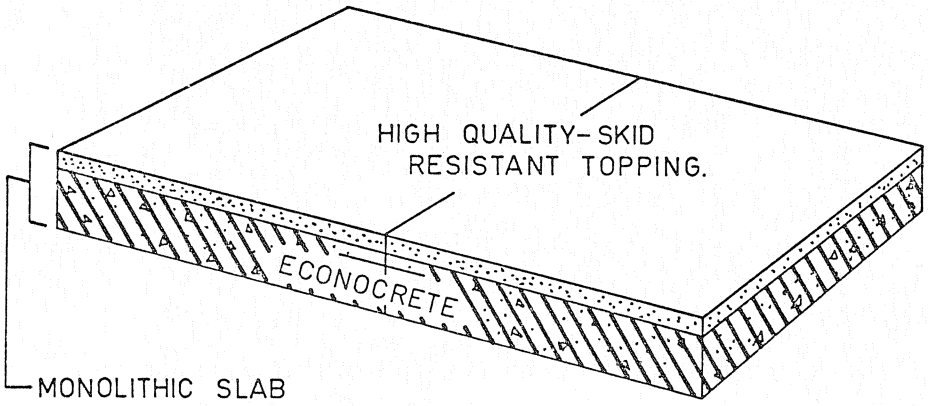
Sieve Size	% Passing
1"	100
3/4"	95.2
1/2"	78.9
3/8"	69.6
#4	53.4
#8	37.0
#10	33.8
#16	25.4
#40	15.4
#50	13.6
#200	8.5

Figure 4



ELASTIC MODULUS NOMOGRAPH — OCALA LIMEROCK

Figure 5

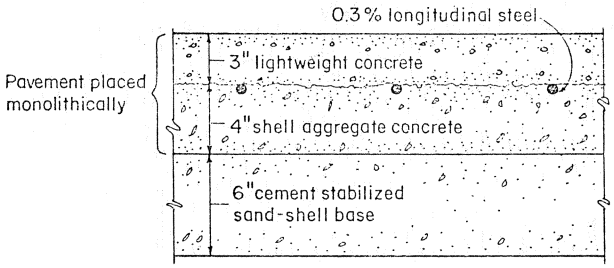


COMPOSITE PAVEMENT

Figure 6

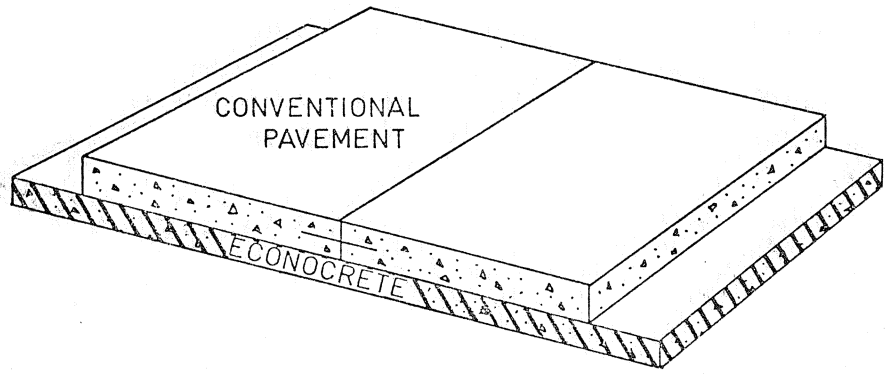


Figure 7



COMPOSITE CRC PAVEMENT, HOUSTON, TEXAS

Figure 8



SUBBASE FOR CONCRETE PAVEMENT

Figure 9

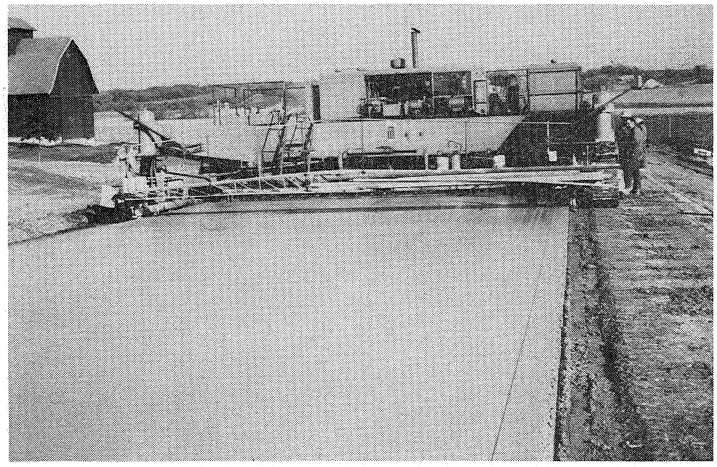


Figure 10

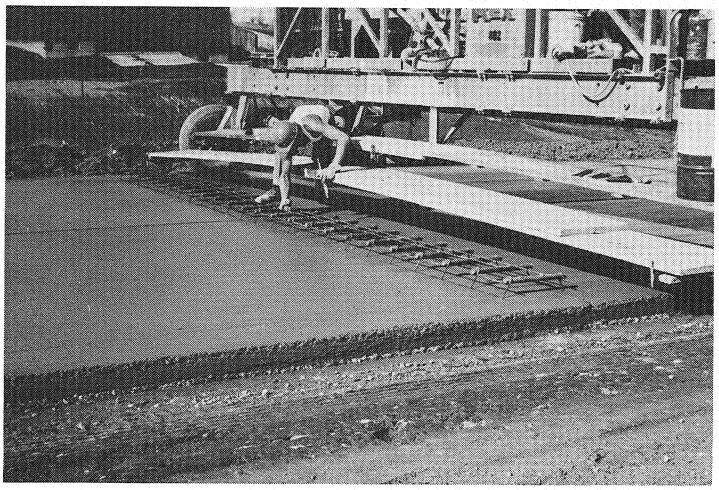
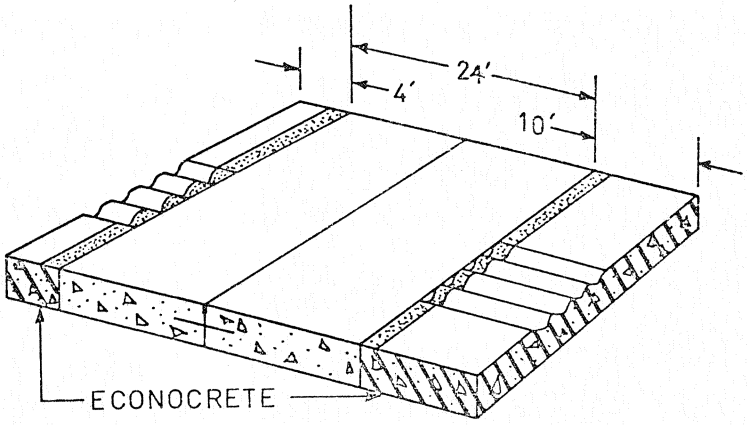
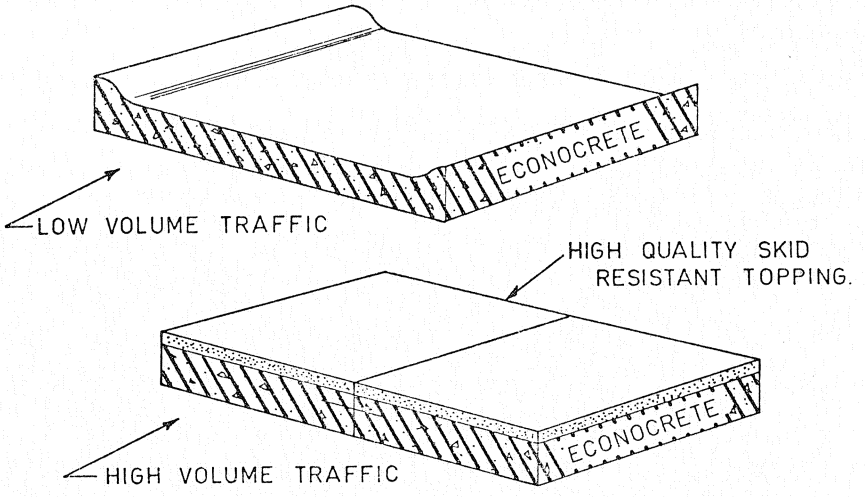


Figure 11



CONCRETE SHOULDERS

Figure 12



STREET PAVING

Figure 13