EXECUTIVE SUMMARY

Iowa's county road system includes several thousands of miles of paved roads which consist of portland cement concrete (PCC) surfaces, asphalt cement concrete (ACC) surfaces, and combinations of thin surface treatments such as seal coats and slurries. These pavements are relatively thin pavements when compared to the state road system and therefore are more susceptible to damage from heavy loads for which they were not designed. As the size of the average farm in Iowa has increased, so have the size and weights of implements of husbandry. These implements typically have fewer axles than a truck hauling the same weight would be required to have; in other words, some farm implements have significantly higher axle weights than would be legal for semi-trailers. Since stresses induced in pavements are related to a vehicle's axle weight, concerns have been raised among county and state engineers regarding the possible damage to roadway surfaces that could result from some of these large implements of husbandry.

Implements of husbandry on Iowa's highway system have traditionally not been required to comply with posted weight embargo on bridges or with regulations regarding axle-weight limitations on roadways. In 1999, with House File 651, the Iowa General Assembly initiated a phased program of weight restrictions for implements of husbandry.

To help county and state engineers and the Iowa legislature understand the effects of implements of husbandry on Iowa's county roads, the following study was conducted. The study investigated the effects of variously configured grain carts, tank wagons, and fence-line feeders on Iowa's roadways, as well as the possible mitigating effects of flotation tires and tracks on the transfer of axle weights to the roadway. The study was accomplished by conducting limited experimental and analytical research under static loading conditions.

A section of an ACC pavement on County Road K52 in Sioux County and a section of a PCC pavement on E-29 in Jones County were instrumented for testing and were analyzed under different loading types. The pavements selected were instrumented to measure strains, temperature, and moisture. These sensors were installed during construction. Instrumentation was positioned as close as possible to areas that typically resist high tension stresses due to vehicle traffic. In the PCC pavement, these areas are near the surface at the joint/edge corners and near the bottom along the pavement edge. In the ACC pavement, the sensors were attached to the top of the first lift or about 3 inches up from the sub-grade and under the wheel path. The pavements were tested at crawl speeds, less than 5 mph, under vehicle-of-husbandry and standard-truck loads. Data were collected at 100 samples per sensor per second. Tape switches were also positioned on the pavement surface during testing so that vehicle position could be determined in correlation with the collected data. The data were then used to calibrate and verify the analytical models.

The two pavement types were analyzed under the loads used in the test. The analyses were accomplished using simplified methods. Finite element analyses were also conducted to verify the simple analysis results of the PCC pavements. Soil-pavement interaction was included in the finite element analyses utilizing plate on dense liquid foundation theories. The sensitivity of the results to the size elements was investigated. To gain confidence in the analytical

modeling, the results were compared to those obtained from the field test. Some discrepancies between the analytical and the field test results were noticed. These most likely were due to the uncertainty of the values of the parameters, such as the soil sub-grade reaction, and the actual elastic modulus and the thickness of the pavement. In spite of this discrepancy, both analytical and field test results revealed similar behaviors for the PCC and ACC pavements. Three additional PCC and ACC pavements with different thicknesses and under different loading configurations and seasonal conditions were also analyzed. PCC pavements with thicknesses of 7, 8, and 9 inches and ACC pavements with thickness of 8 inches, along with typical design values of sub-grade reactions and pavement material properties, were considered. The dual-wheeled, single-axle configuration (20,000-lb) was taken as the reference loading. The critical strain or stress calculated under this load was taken as the reference response. The other tire/axle configuration weights and consequently the tire-pavement contact areas were varied until the program indicated the same critical response as the reference loading had been returned.

The analyses illustrated that during the spring season, a single-axle, single-tire grain cart or liquid manure tanks ("honey wagons") with flotation tires and an axle load of approximately 24,000 lb. would have the same effect on ACC pavements as that caused by a 20,000-lb.,single-axle, dual-tire semi-trailer. During the fall season, this load capacity was increased to 28,000 lb. due to the seasonal change in the soil sub-grade reaction. In addition, the increase of the axle weight of multiple-axle wagons was insignificant. This was expected, since the spacing between the axles is large enough compared to the pavement thickness. In other words, one can analyze the behavior of a pavement structure under multiple axles by considering each axle separately. Similar behavior was observed when analyzing the PCC pavements. However, a slight increase in the axle load was obtained when considering the fall condition. This can be attributed to the difference in the behavior of the flexible ACC and rigid PCC pavements.

The field test and the analytical results demonstrated that tracked vehicles induce lower stress or strain values in both PCC and ACC pavements when compared to other loads. However, these results must be interpreted with caution since the analysis assumed that the load of these vehicles is transferred to the pavement uniformly over the track-pavement contact area rather than at discrete locations along the lugs of the track. Exact load path to pavement must be carefully investigated prior to making firm conclusions regarding the benefits associated with these types of implements.