Yucca Mtn.

State of California

Business, Transportation and Housing Agency

# Memorandum

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From: **DEPARTMENT OF TRANSPORTATION**
**DIVISION OF ENGINEERING SERVICES**
**MATERIALS ENGINEERING AND TESTING SERVICES - MS #5**

Subject: **Analysis of Pavement Response Under Multiaxle Superheavy Load Transportation Vehicle - Preliminary Investigation (Special Study)**

As requested by District 6 Materials Engineer Office, we have completed a preliminary evaluation of the impact of superheavy load hauler (SHLH) on State Route 127 (SR 127) for transporting nuclear waste to the proposed radioactive waste repository test site at Yucca Mountain, Nevada. The SR 127 is a rural two-lane conventional highway and is functionally classified as a minor arterial. SR 127 is not included in the Subsystem of Highways for the movement of Extra-Legal permit Loads (SHELL) system, nor AB 866 or the Federal Highway Administration (FHWA) regard it suitable for larger trucks, according to the draft FSR.

Major rehabilitation work is proposed by the District to the existing traveled way in order to insure safe operating conditions along the entire route. This includes constructing or widening shoulders and correcting horizontal and vertical alignments within the proposed limits, as described in the draft Feasibility Study Report (FSR) dated February 28, 2002.

As part of the evaluation of suitability of SR 127 for this kind of transportation, this report only presents an assessment of response of the existing pavement structural section to the superheavy load being transported using a specially designed truck-trailer axle/tire configuration.

## Truck-Trailer Supeheavy Load Hauling System

A schematic of the transportation system proposed for use in hauling canisters (casks) of radioactive materials is shown in Figure 1. The overall length of the trailer system is 51.82 m (170 ft) and the width of the running gear can be set to either 3.66 m (12 ft) or 4.27 m (14 ft). This width exceeds the California maximum allowable vehicle width of 2.59 m (8.5 ft). This transportation system consists of 8 tandem axle assemblies, and each axle consists of four dual tires (i.e., 8 tires per axle), for a total of 16 tires per assembly. The total number of tires for the SHLH is 130 (=1×2+8×16). The gross weight of the hauling system is 227.96 tonnes (502.125 kips) distributed as follows: tare weight=71.16 tonnes (156.75 kips), beams weight= 20.60 tonnes (45.375 kips), and loaded cask weight=136.20 tonnes (300 kips).

The distribution of the gross weight on the proposed axle configuration shown in Figure 1 is as follows (www.state.nv.us/nucwaste/trans/pic3/fig03a.htm):

- Steering axle #1 (single axle with single tire) will carry 18.4 kips (3.6%). Each tire will be loaded to 9.20 kips. This axle loading is California-legal and will not be analyzed in this study.
- Tandem axle (# 2+3) will carry 44.4 kips (8.8%). Each tire will be loaded to 2.775 kips.
- The remaining tandem axles (# 4+5, 6+7, 8+9, 10+11, 12+13, 14+15, 16+17) each will carry 62.8 kips (12.5%). Each tire will be loaded to 3.925 kips.

Note that the California limits on loading are: 20 kips for single axle, 34 kips for tandem axle with four-foot spread, and 80 kips for the maximum allowable gross weight.

**Field Testing and Backcalculation of Moduli**

Nondestructive deflection testing using falling weight deflectometer (FWD) was performed on August 6-8, 2002 by the Office of Structural Section Design & Rehabilitation (OSSDR) on a number of locations within the project limits. Cores were also retrieved from twenty locations to determine thickness and type of materials within the structural section.

For the purpose of this preliminary analysis, a relatively weak structural section was selected by examining the backcalculated modulus of asphalt concrete and inspecting deflection data obtained at various locations. Table 1 summarizes the deflections measured and cores obtained at twenty locations. The section selected for analysis was at PM 15.11± in San Bernardino County in southbound direction of SR 127. The core obtained at that location (#15 in Table 1) revealed approximately 183 mm (7.2 in.) of dense graded asphalt concrete (DGAC) overlaying 56 mm (2.2 in.) of road mixed asphalt concrete (RMAC), over sandy to sandy-silty native subgrade soil (see Fig. 1-c for the structural section).

The deflection data were used to backcalculate elastic moduli of the structural section layers using multilayer elastic (MLE) theory. The Evercalc© software developed and distributed by Washington DOT was used in backcalculating layers moduli. For the 7.2"/2.2" section analyzed, the following backcalculated elastic moduli were obtained:

- DGAC= 1486 MPa (215.78 ksi)
- RMAC= 172 MPa (25.0 ksi)
- Subgrade soil=100 MPa (14.56 ksi)

**Stress-Strain Analysis of Structural Section**
Asphalt concrete pavements primarily fail by fatigue or rutting. The tangential tensile strain at the bottom of DGAC ($\varepsilon_t$) is usually related to the fatigue failure of the structural section, whereas the vertical compressive strain on the top of subgrade ($\varepsilon_c$) affects the permanent deformation (rutting). When the critical $\varepsilon_t$ and $\varepsilon_c$ strains are plugged in appropriate transfer functions (failure criteria) representing the relationship between strain and number of load repetitions to failure by fatigue or rutting, pavement life could be determined. Also, the reduction in pavement life due to use of loads heavier than what the pavement was designed for could be estimated.

The Washington DOT Everstress© based on MLE theory was used to compute stresses and strains under a number of loading scenario at various locations within the structural section. For the purpose of the present analysis, SHLH system and the conventional single axle and tandem axle systems with single and dual tires were analyzed and compared. The purpose of this comparison was to determine whether the truck-trailer system proposed for transporting heavy loads of nuclear waste would induce higher stresses and strains in any layer within the pavement structural section compared to the traditional transportation systems permitted on California pavements.

The strains induced by SHLH were compared with strains generated by three traditional loading systems normally permitted on California pavements:

- 20-kip single axle with single tire (SAST),
- 20-kip single axle with dual tires (SADT), and
- 34-kip tandem axle with dual tires (TADT).

Table 2 summarizes the estimated critical (maximum) $\varepsilon_t$ and $\varepsilon_c$ resulting from each of the analyzed four loading systems using the critical three-layer structural section shown in Fig. 1-c with their backcalculated moduli. A tire pressure of 120 psi was used in the analysis. As seen in Table 2, the superheavy load transportation truck-trailer system generally does not induce larger strains in DGAC layer or subgrade material than those normally generated by the permitted traditional axles for the structural section analyzed in this study. Compared to 34-kip TADT system, the SHLH induces slightly higher (about 7%) $\varepsilon_t$ at the bottom of DGAC layer. For permanent deformation, the SHLH seems to be less damaging to the pavement structural section than the other permitted loading systems analyzed. This is primarily attributed to lower load per tire on the SHLH assembly and the relatively large spacing between axles.

For analyzing the damage that could be caused by the SHLH, the equivalent axle load factor (EALF) was also determined. This factor defines the damage to pavement per pass by the axle in question relative to the damage per pass of some standard axle load. The EALF can be related to both $\varepsilon_t$ and $\varepsilon_c$ using proper failure criteria. The EALF's of SHLH relative to the three traditional axle configurations are summarized in Table 3. For their impact on fatigue life, one pass of one SHLH tandem axle assembly is estimated to be equivalent to 0.238 passes of the 20-kip SAST. In other words, one pass of 20-kip SAST induces same amount of fatigue damage to the pavement as approximately four passes of the tandem axle of the SHLH. Relative to the 20-kip SADT, the fatigue EALF increases to 0.652, and relative to 34-kip TADT it increases to 1.329. Only for the last case where one pass of the tandem axle of the SHLH will cause more damage than a standard 34-kip TADT.

The EALF's of the tandem axle of the special hauling system based on rutting damage are more conservative than those for fatigue. For example, based on 20-kip SAST, approximately 13 passes of one tandem axle assembly of the SHLH cause same permanent deformation to the pavement structural section as that caused by a single pass of a standard 20-kip single axle with single tire.

**Conclusions**

1. Analysis of the truck-trailer system proposed for use in transporting nuclear waste via SR 127 to the repository site at Yucca Mountain indicated that this transportation system will not induce more damage to the pavement than the conventional transportation systems normally permitted on California pavements. While this conclusion is based on analyzing one of the weakest structural sections tested, it is expected to remain valid for other sections.

2. The pavement may require rehabilitation (e.g., overlay, mill/replace, etc.) to meet the normal traffic loading and the additional loading that would be imparted by the transportation of nuclear waste. Also, the route requires some level of reconstruction that includes correcting horizontal alignment, adding new and widening existing shoulders, and possible widening of mainline, as suggested in the draft Project Study Report. For this purpose, the normal design procedure based on R-value can be used.

3. For structural section design, the contribution of the SHLH to the total projected traffic loading in EASL's can be assessed using the equivalency factors (EALF's) based on fatigue damage determined for the analyzed SHLH.

4. Additional deflection testing will be performed to cover the entire project limits, and rehabilitation recommendations will be issued by OSSDR.