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Simulation of a Mobile Crane's Dynamic Load Using the CraneSim Program

RESULTS: The CraneSim computer program was developed to analyze the dynamic loads generated by mobile cranes. Different crane configurations and suspension systems can be compared using the Dynamic Load Coefficient. The analysis shows the single most important factor affecting crane dynamic loads is the type of suspension. As a result, modern cranes with hydro-pneumatic suspension systems can generate dynamic loads that are up 20 percent lower than traditional suspension systems.

Why this research is important

The high level of pavement deterioration on major urban roadways can be attributed to a significant increase in traffic, particularly from large trucks. Pavement damage increases exponentially as load increases. Overall travel on urban roads increased by 30 percent between 1991 and 2001. Travel by large commercial trucks increased by 46 percent over the same time period. According to a recent report[1], vehicle travel is projected to increase by 42 percent by 2020, while travel by heavy trucks is projected to increase by 49 percent.

To protect and preserve our existing infrastructure, the California Department of Transportation (Caltrans) conducted a study to learn the effect of various heavy vehicles on our highway system. The quantification of these effects will enable us to issue permits that better reflect the damage various heavy vehicles caused to pavements. One of the heavy vehicles using our highways is the mobile crane. But there is virtually no research evaluating the effects of mobile cranes on the highway system.

Figure 1: Typical Crane Configuration in Operation

These modern cranes have different wheel and suspension systems to redistribute the carrying loads to meet our axle load limits. Caltrans currently uses static loads based on the axle spacing and load limits to issue permits. In order to meet the permit requirement, modern cranes employ different wheel configuration and suspension systems to redistribute the static loads. This approach disregards the dynamic load created by a moving vehicle on the uneven road surface. It is important for Caltrans to have a tool to quantify the effect of various wheel configurations and suspension systems on the pavement loading as it will allow us to evaluate these newly developed crane structures and understand how they affect our highway system. As a result, Caltrans can develop a more effective regulation of axle load limits and encourage the adoption of appropriate new vehicle regulations.

Figure 2: Typical Crane Dolly Configuration

Research results

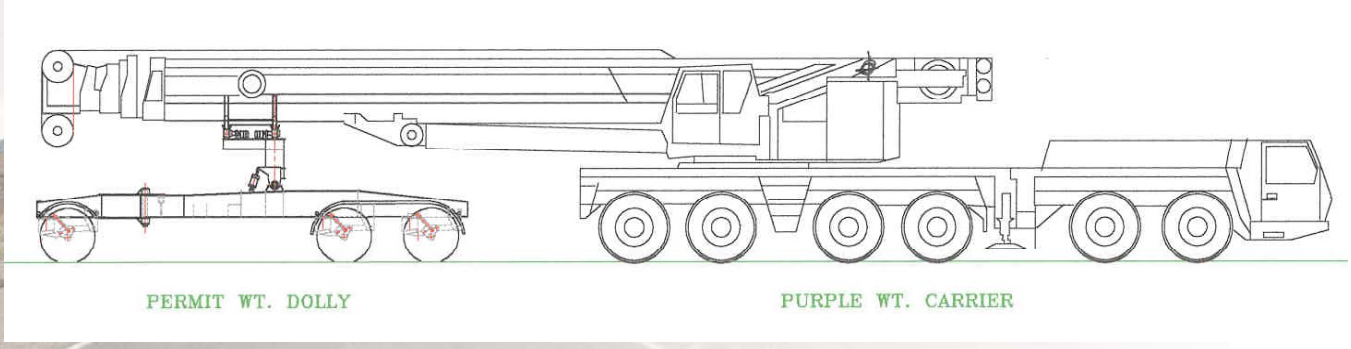
The Pavement Research Group (PRG) initiated this research at the request of Caltrans' Division of Traffic Operations, with support from the crane industry. The Caltrans PRG and Advanced Highway Maintenance Construction Technology (AHMCT) research teams concluded that the most significant factor contributing to pavement damage is the interaction between the crane and the roughness of the pavement. It is believed that as the road gets rougher, the dynamic loading of the roadway also increases.

The questions posed by the Division of Traffic Operations were:

1) Can differences in the suspension system decrease the dynamic loading?
2) If so, by what percentage?

An analytical tool was developed to compare modern and conventional suspension systems.

Figure 3: CraneSim is used to Analyze Carrier and Dolly Model



Working with several crane manufacturers**,** AHMCT developed a computer program called CraneSim. CraneSim is a tool that incorporates many crane wheel configurations and suspension systems to develop an understanding of dynamic loads on our pavement system. Several different cranes and heavy vehicle configurations were developed for the program, such as the traditional lattice and telescoping booms, different dolly configurations, four- and six-axle modern hydro-pneumatic carriers, and semi-trailer and truck.

We defined the Dynamic Load Coefficient (DLC) as

$$DLC = \frac{RMSDynamicLoad}{StaticLoad}$$

where RMS dynamic load is the root-mean square of the dynamic loads calculated by the CraneSim computer program. If the value of DLC is 1, the dynamic load is same as the static load. If the value of DLC is greater than 1, the dynamic load is higher than the static load. DLC can be visualized as an index that relates the dynamic load to the static load. Using DLC, comparisons can be made among different cranes and trucks.

Conclusions

When compared with the existing research literature[1] simulations produced by CraneSim capture the fundamental dynamic loads generated by mobile cranes with reasonable accuracy.

Analysis shows suspension type is the single most important factor affecting crane dynamic loads. Hydro-pneumatic suspensions found on modern hydraulic crane carriers are far superior to the traditional walking beam. The walking beam excites significant motion of the carrier mass and boom, while the hydropneumatic suspension reduces the dynamic effect from the road roughness. As a result, the modern cranes using hydropneumatic suspension systems reduce dynamic loads by as much as 20 percent when compared to cranes with more traditional suspension systems.

The CraneSim analytical tool developed in this research will enable the Division of Traffic Operation to evaluate various crane wheel configurations and suspension systems, thereby facilitating a more realistic approach to issuing permits.

References

[1] *"Cost of Rough Roads Reported,"* AASHTO Journal, May 30, 2003
[2] *"Handbook of Vehicle-Road Interaction,"* David Cebon, Swets & Zeitlinger Publishers, 1999

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