A SIDE-BY-SIDE ANALYSIS OF MAINE INTERSTATE BRIDGES

ANALYSIS TOOL

The model used in this analysis is the Bridge Analysis and Structural Improvement Software (BASIC) model. TransTec, Inc., with support from faculty members at the University of Texas, developed the model under contract to FHWA. The model computes the live load and total load bending moment for any truck configuration, for any span length, for most bridge types, and for both continuous and simple span bridges. Additionally it computes the ratio of those moments to the NBI reported inventory or operating rating.

The model computes live load bending moments for most all common bridge types for each inputted truck. It handles up to 15 trucks in one batch run. It also computes the total bending moment, that is, live load and dead load. It uses a look-up table of representative dead loads for most bridge types (reinforced concrete, steel girder, prestressed concrete T beams, etc.) and span length. It includes lane loadings that Akick in@ according to AASHTO procedures. Although the model can handle the most prevalent bridge types, it cannot analyze suspension, movable, timber and a few other unusual bridge types because there are no deadloads for these types of bridges in the lookup table.

The model has other limitations. These limitations are based primarily on the limitations of the National Bridge Inventory (NBI) data. For example, the NBI only contains the span length of the main span and the total bridge length. Consequently, when the model computes moments for a continuous bridge it assumes that the minor span lengths are equal to(the total length less the length of the main span divided by the number of spans minus one. Another example of data limitations is that the NBI reports inventory and operating ratings based on the "weakest link." This, of course, makes sense and is not a problem on simply supported bridges where the weakest link is at the center of the "weakest" span. On continuous bridges, however, the "weakest" link may be near the middle of a span, but the moment caused by a truck over the interior supports (the negative moment region) may be much greater and the state may design this area to withstand these greater stresses. The problem is the NBI does not report the rating in the negative moment regions.

Despite, these limitation, BASIC has proven to be quite accurate and a powerful tool to identify problem bridges. Although not used in this analysis, BASIC also has the ability to estimate delay and pollution costs associated with bridge replacement. It assumes that the number of lanes are reduced (e.g. for the replacement of two-lane bridges, it assumes that one bridge is kept open while the other is replaced, thereby reducing the flow to one lane in each direction) and the model applies queuing theory to estimate delay and the subsequent increased pollution. It also applies State-specific unit construction costs to estimate replacement costs if the model calls for the bridge to be replaced. It computes the square footage of the replacement bridge and then applies the unit cost to estimate the replacement cost. It also permits the user to apply an expansion factor to these costs to account for the invariably larger replacement bridge.

ANALYSIS RESULTS

The Excel Workbook, me-inv2c.xls, contains five spreadsheets:

1. Vehicles
2. Total Moments vs Inventory Rating
3. Total Moments vs Operating Rating
4. Total Moments vs Short 80 k BFB Truck
5. Total Moments vs Long 80 k BFB Truck

1. Vehicles

This sheet describes the fifteen vehicles I analyzed. The first vehicle is the HS20 vehicle with the short wheelbase. I included this vehicle because it represents the standard design vehicle for most of the bridges in the US. Vehicles numbered 6 and 7 were the heaviest legal trucks allowed on the interstate system in Maine until the recent change passed in December. The remaining 12 vehicles represent the heaviest legal trucks of the most pertinent axle configurations. Some of these trucks represent exceptions for certain commodities from the standard legal trucks in Maine.

Format

The first column is an assigned vehicle number and the next column a description. The next 6 columns are the axle loads in pounds, with Axle No. 1 being the steering axle. Next are the axle spacings in feet, then the GVW, the wheel base and lastly a column of explanation codes.

2. Total Moments vs Inventory Rating

This sheet presents the maximum positive and negative moments on the subset of bridges caused by the inventory rating (as reported in the year 2009 NBI) vehicle and each of the 15 candidate trucks. As was stated previously, the model can not analyze all bridge types for several reasons. It can not analyze tunnels or culverts. It performs an error check and discards bridges with inconsistent data1 and lastly it can not analyze the total moment for bridges for which there is no dead load approximation in the lookup tables. (It can analyze, however, live load moments for these bridges.) The model does produce a "Bug" file that briefly describes why it could not analyze a particular bridge. Of the 253 real and open Interstate highway bridges in Maine, the model did analyze 209 of the bridges, or 83%.

Format

The first column is the state's Structural Number, the second is an Index Number generated by the model. The next three columns are the Maximum Positive Moment (in inch-pounds), the Maximum Negative Moment and lastly the Ratio of the Max Moment to the Inventory Rating. This of course will always be 1, since the ratio of the inventory rating to itself must be, naturally, 1.0.

The next four columns, which are repeated for the remaining 14 trucks, are:

1. Max Maximum Positive Moment
2. Maximum Negative Moment
3. Ratio of the Max Moment to the Inventory Rating Moment
4. Indicates the region (positive or negative moment region) which contains the highest ratio of the maximum moment to the inventory rating moment.

These four columns are repeated for all fourteen trucks. The turquoise highlighting indicates whether the maximum moment ratio (not the maximum moment) is in the positive or negative moment region.

Below the main body of output for each truck is a column of numbers representing the percent of bridges that are "overstressed" by more than 5, 10, 20, 30 , 40 and 50 percent, where "overstress" is defined as causing a stress greater than the inventory rating.

Results

These results are quite interesting. If one assumes that greater than a ten percent "overstress" (defined as a stress 10% greater than the stress caused by the inventory rating vehicle) is unacceptable, ***then these results show that every 100,000 lbs. truck is a problem***. The least damaging of these trucks (Truck number 11 – the long wheelbase 100 kip CS6) produces greater than 10% mores stress in 38% of the Maine interstate bridges and stresses greater than 20% in just over 17% of these bridges.

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[1] For example, in some records the total bridge length is less than the length of the main span, an obvious coding error.

It should be remembered that the bridge rating reported in the NBI probably reflects a rating computed by the more conservative Load Factor method (relative to the new and less conservative Load Resistance Factor method). Consequently, the NBI ratings are conservative and most bridges will be rated higher once they are analyzed using the LRFD method. Nonetheless, the results should cause prudent bridge engineers some concern.

3. Total Moments vs Operating Rating

This sheet presents the maximum positive and negative moments on the subset of bridges caused by the operating rating (as reported in the year 2009 NBI) and each of the 15 vehicles. The operating rating is necessarily greater than the inventory rating. It is based effectively on a reduced factor of safety. For example, in the old allowable stress method the operating rating was 36% higher than the inventory method. Computing the operating rating using the LFD or LRFD methods will produce a greater rating than the inventory rating, but the percent greater will vary.

Many states use the operating rating as the maximum stress level allowed for permit trucks. In other words, if a truck produces stress greater than the stress caused by the operating rating vehicle, then either the state would not issue the permit or would undertake a detailed analysis of the bridge and then allow the truck to use it once other special conditions are met. Such could include greatly reduced speed, stopping all other traffic, temporary reinforcing critical members, etc. No state, to the best of my knowledge, allows unlimited or even general permit use of trucks that produce stresses that exceed the stresses caused by the operating rating vehicle.

Format

The format of this spreadsheet is identical to that in the previous spreadsheet.

Results

IF the operating ratings area correct, these results indicate that, for the most part, Maine's interstate bridges can accommodate the ***occasional*** 100,000 lbs. truck, since the worst candidate truck produces a stress greater than 10% more than the operating rating on only 4.3% of the birdies. I feel that the operating rating reflects and unacceptable reduction of the factor of safety contain in the inventory rating and therefore it would not be prudent to allow unlimited numbers of these heavier trucks. Moreover, there are several key issues to consider:

1. Past research has shown that the Operating Rating is generally less accurate than the inventory rating.

2. The bridges on which the stress is greater than even 5% more than the operating rating should be rigorously analyzed and inspected.

4. Total Moments vs Short WB 80k BFB Truck

Format

This spreadsheet is similar to the previous one, except the comparison moments are to the short wheelbase BFB 80kip CS5 that was the legal limit on the non-toll interstate system in Maine prior to the legislation passed in December.

Results

The results of the analysis are presented on the third spreadsheet of the workbook, and they reveal some interesting numbers. Every 100 kip truck except one, Truck #11 the 58 foot wheel base CS6, produces stresses 10% greater than the standard 80k CS5 on over 60% of the bridges, however, the number of bridges that would experience stresses greater than 40% of the stresses caused by the 80 kip truck is negligible.

5. Total Moments vs Long WB 80k BFB Truck

Format

This spreadsheet is similar to the previous one, except the comparison moments are to the long wheelbase BFB 80kip CS5.

Results

In general the side-by-side results of comparing the candidate trucks to the long WB 100 kip CS6 are similar to those comparing them to the short wheelbase 100 kip CS6.

CONCLUSIONS

It is not possible to definitively determine the added level of damage that these 100 kip trucks will on the Maine's Interstate system bridges without a detailed inspection and analysis of each bridge. The system-wide analysis I performed does provide valuable insight into those bridges that need a much closer look. There is absolutely no question that these truck will produce stresses significantly higher than the 80 kip truck.

There is also very little probability that these trucks will cause any bridge failures in the near future. However, most bridges in Maine are steel bridges, which are prone to fatigue problems, especially in the light of large amounts of salt used to melt snow int the winter. Although fatigue damage can be repaired fairly cheaply if identified early, this puts an extra burden on the state to improve the quality and quantity of inspections. It also comes down to the issue is how much of the designed factor of safety is Maine willing to sacrifice. Relatively large factors of safety are inherent in bridge design, and Maine's interstate bridges were not designed for 100,000 lbs. trucks. This analysis shows that a significant number of bridges will have their factor of safety reduced significantly.

The statement below is somewhat editorial and reflects only my personal opinion.

The decision to request the Federal waiver of BFB and the 80 kip cap may have been partially based on safety and other issues, but the real effect it that it is in the state's interest to shift the responsibility of repairing bridge and pavement from the State to the Federal government. Indeed while there may be some safety benefits, the fact remains that this simply transfers significant repair costs. In my opinion it is the wrong solution. If there is a safety issue and damage issue on the Maine system, then the solution is to apply Bridge Formula B with an 80 kip cap to the Maine system.