Infrastructure Challenges

Workshop

OECD / ITF Study on
Truck Transport Safety, Productivity and Sustainability

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Outline

- Effects on Pavements
  - Pavement issues
  - Effect of axle configuration
  - Methodology

- Effects on Bridges
  - Methodology
  - Extreme loads and load effects
  - Fatigue

- Other Impacts
  - Impacts on safety barriers, bridge piers and tunnels
  - Impacts on road perception and operations

- Conclusions and Recommendation
Pavement issues

- If pavements and trucks are developed together, transport is facilitated while reducing its cost.

- It requires to take into account many aspects:
  - Environment
    - Pavements (type, strength, …)
    - Climate
    - Availability of resources (aggregates, soils, …)
  - Truck configurations
    - Axle load
    - Group of axles (number, spacing)
    - Wheel and tyres
    - Load distribution
    - Suspensions and steerable axles
Example: influence of axles and tyres

Axle group load

Aggressiveness against a 40T HGV

- Tridem single tyres spacing 1m35
- Tridem dual tyres spacing 1m35
- Tridem dual tyres spacing 1m40
- Tridem dual tyres spacing 1m60
- 3 isolated dual tyres (spacing > 2m)

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Method for evaluating truck aggressiveness

- Relative Vehicle Wear Factor: \[ VWF_{rel}(\text{truck}_x) = \frac{VWF(\text{truck}_x)}{VWF(\text{truck}_{ref})} \]

- Reference truck
  
  \[ \text{40 t / 16.5 m} \]

- Wear factor of a group of axles:
  \[ WF_{\text{group of axles } i} = k_i \left( \frac{W_i}{W_{ref}} \right)^{\alpha_i} \]

  where:
  - \( k_i \) and \( \alpha_i \) are two parameters which depend, for each group of axles \( i \), on the type of pavement and the expected traffic volume;
  - \( W_i \) is the total weight carried by the group of axle \( i \);
  - \( W_{ref} \) is the total weight carried by the equivalent reference group of axles.

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Bridge issues

- Bridges are key/critical elements of the road network
- Bridges must be: reliable, safe, durable, and not too costly
- Heterogeneous bridge stock (ages, design, state, etc.)
- Traffic loads evolve with time: truck configurations, weights and dimensions
- Comparison/assessment of different truck configurations against aggressiveness
- Extreme load effects
- Fatigue (repeated loading)

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Traffic loads and load effects

- Modelling bridges as beams: simple supported, continuous (2-3 spans)
- Influence lines: transfer functions
- Bending moments + shear forces
- \( L = 10, 20, 50 \) and \( 100 \) m
- Calculation done for 39 heavy vehicle configurations (OECD)
- Maximum load effect (1 truck)
- Fatigue: \((\text{Max-min})^\alpha\), \( \alpha = 3, 5 \)
- Comparison to a reference 40 t articulated truck

Bernard JACOB, LCPC, 2010/1/10
## Heavy vehicle configurations

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Aggressiveness (max load effect)

Coefficient of aggressiveness (truck n) : \( K_n = \frac{\text{Max}(S_n)}{\text{Max}(S_{\text{ref}})} \)

Ex.: 10 m simple supported beam, shear forces
Maximum load effects and US bridge formula

- US bridge formula limits the total mass carried by any series of consecutive axles in a truck or combination:
  \[ W = 500\left(\frac{L \times N}{(N-1)} + 12N + 36\right) \]  (W in lbs, L in ft)

- Ex: 5-axle articulated 16.5 m = 73730 lbs or 33.5 t max (40 t in EU), \( c_{\text{ref}} = 40/33.5 = 1.194 \)
  - US-1: \( c_n = 0.903 \), \( C_n = 0.756 \)
  - AUS-2: \( c_n = 1.232 \), \( C_n = 1.03 \)

- For any truck \( n \): \( c_n = W_n / W_{bf} \), \( C_n = c_n / c_{\text{ref}} \) load coefficient

- Comparison of \( K_n \) and \( C_n \)
Aggressiveness 1 – max mid-span moment

Coefficient mid span moment

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Aggressiveness 2 – max moment on pier

Coefficient pier moment

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Aggressiveness 3 – all lengths vs max effects

Coefficient max / Load effect

- Mid span moment
- Pier moment
- Shear force
- Mean
- Bridge Formula

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Fatigue aggressiveness

- Miner’s law + S-N curve (resistance to fatigue)
- Assumptions (crude !):
  - one truck run → one stress cycle ΔS (for moment on pier x 2 !)
  - 40 t reference truck → (Max S – min S) ≡ ΔS* (fatigue limit)
  - coefficient of aggressiveness: $K'_n = (\Delta S/\Delta S^*)^\alpha$
- where $\alpha=3$ if $\Delta S>\Delta S^*$ and $\alpha=5$ if $\Delta S<\Delta S^*$
- Bridge formula: $C_n = (c_n/c_{ref})^\alpha$
  where $\alpha=3$ if $c_n>c_{ref}$ and
  $\alpha=5$ if $c_n<c_{ref}$

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Aggressiveness 1 – fatigue mid-span moment

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Aggressiveness 2 – fatigue moment on pier

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Dynamic amplification, traffic load and stress monitoring

- DAF rarely exceeds 1.1 to 1.2
  - for heavy loaded vehicles
  - for more than one truck on a bridge
- 1.05 applies to extreme load cases

**B-WIM:**
- mature technology
- more bridge types
- more parameters
- part of bridge monitoring systems

Bridge (B-)WIM is an appropriate tool: stress + load +…
Impacts on safety barriers, piers and tunnels

- **Safety barriers**: designed for a given vehicle mass, speed and impact angle, e.g. EN 1317 H4b: 38 t, 65 km/h, 20°

- Design depends on: consequences of an accident, traffic volume, type of road, local conditions/geometry, etc.

- **Bridge pier**: design + protection, FE calculations

- Not all trucks contained, decisions to be taken for LHV's...

- **Tunnels**: main issue is fire, up-grade of the EU legislation since the Mt Blanc fire (1999)
  - dangerous goods to be monitored
  - permanent access and inter-distance control
  - maintenance + fire detection/suppression in trucks
  - fire resistant materials, fuel tank protection
  - driver education and training
Impacts on road perception and operation

- **Road perception:**
  - … and visibility affected, leads to “improper maneuvering”
  - length and distance underestimation ! Overtaking !
  - splash and spray in wet conditions, - night time signaling

- **Road traffic operation:**
  - to smooth the traffic flow and reduce congestion:
    - speed limit harmonization (between trucks)
    - overtaking limitations/bans
    - to locally allocate dedicated lanes to trucks
  - to improve safety and efficiency:
    - crossings and turns design, LHV’s prohibited in some area/sections
    - adapted speed limitation vs. the infrastructure (roundabout, curves…) and the vehicles (load, height of the gravity center, performances…)
    - extension of parking lots
    - IAP (Int. Access Program) to be developed
Conclusions and recommendation (1)

PAVEMENTS

- Axle loads and configurations are much more important than the gross vehicle mass
- Distributing the load evenly among all the axles substantially reduces the aggressiveness
- Method exists to evaluate these aspects respecting the characteristics of the studied network
Conclusions and recommendation (2)

BRIDGES

- Truck aggressiveness mainly depends on the axle loads and the UDL (kN/m)
  → do not increase axle load, increase truck length more than load
- The heaviest trucks govern some bridge effects (medium span, semi-local effects), multiple presence events and long spans, fatigue can be an issue
- The US federal bridge formula is applicable for short/medium span bridges, has been designed for 20 m / 73 200 lbs trucks. To be updated and extended.
- Dynamic effect is NOT a major issue, bridge load and stress monitoring can be very effective (e.g. with B-WIM) + IAP and truck routing
Conclusions and recommendation (3)

OTHERS

- Safety barriers and bridge piers to be re-assessed/reinforced (LHVs)
- Better hazard monitoring (truck/driver/infras) in tunnels…
- ITS to be developed for road operation, strategies to be developed for LHV

Thank you!