Do Tandem and Triple Axles Deserve their Bad Reputation?

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Presentation Overview

Introduction
Problem Statement
Approach
- Peak Stress Analysis
- Influence Line Analysis : Combined Axle
Conclusions

Problem Statement

The French SETRA Design Manual states:
with Same Loads on every Axle
Tandem Axle is equivalent to 12 Single Axles
Triple Axles is equivalent to 113 Single Axles

The Detrimental Effect Of Successive Loads (2 or 3) Is Profound When Considered To Single Successive Loads. Conservative or Not?

Scope & Significance

Scope of paper: Determine detrimental effect of Tandem and Triple Axles for a single pavement by means of design calculations

Significance: Detrimental effects of multi-wheel loads on concrete pavements (roads & airports e.g. B777-200LR and -300ER)

Pavement & Load Considered

Stress Distributions

wheel spacing 1.0 m
P=100 kN (1...3)
p=0.70 MPa
rupture =6 MPa

Single Stress
Tandem Stress
Triple Stress

Stress Distributions

Bending stress
Fatigue & Detriment

Analysis of Stresses by means of Fatigue Relationship:

\[
\log N = 13 \times \frac{1 - \frac{\sigma_{\text{bending max}}}{\sigma_{\text{rupture}}}}{1 - 0.75 \times \frac{\sigma_{\text{bending min}}}{\sigma_{\text{rupture}}}}
\]

Computation (1)

**Single axle**

\[
\sigma_{\text{single}} = 1.457 \text{ N/mm}^2
\]

\[
\log N_{\text{single}} = 13 \left(1 - \frac{1.457}{6}\right) = 9.8432
\]

\[
N_{\text{single}} = 6.97 \times 10^9
\]

**Tandem axle**

\[
\sigma_{\text{single}} = 1.729 \text{ N/mm}^2
\]

\[
\log N_{\text{single}} = 13 \left(1 - \frac{1.729}{6}\right) = 9.2538
\]

\[
N_{\text{single}} = 1.79 \times 10^9 \frac{6}{\text{axis}} = 8.95 \times 10^8
\]

Computation (2)

Detriment of a tandem axle is

\[
\frac{6.97 \times 10^9}{8.95 \times 10^8} = 7.79
\]

single axes and not 2.

Detriment of a triple axle is 27.2 single axes and not 3.

Tandem Stress Distribution

Analysis by Means of Combined Axles

**Alternative Approach:** Combined Axle act as Single Load. Break-down of Stress Distribution and Transformation into Influence Line

- Portion of Peak Stress
  - Parts Left and Right of Peak (B-A & D-B)
  - Calculate N1
- Portion between Peak Stresses
  - Middle Part between Peaks (B-C-D)
  - Calculate N2
- Calculate Nf for combined Axle and compare to Nf of True Single Axle

TANDEM (1)
**Introduction**

**Scope**

**Approach**

**Peak Stresses**

**Combined Axle**

**Closure**

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**TANDEM (2)**

![TANDEM graph](image)

**TANDEM (3)**

![TANDEM graph](image)

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**Computation**

\[
\log N_1 = 13 \left(1 - \frac{1.729}{6} \right) = 9.2538, \quad N_1 = 1.79 \times 10^9 \\
\log N_2 = 13 \left(1 - \frac{1.729}{6 - 1.152 \times 1.152}{6} \right) = 10.816, \quad N_2 = 6.46 \times 10^{10} \\
N_{\text{single}} = \frac{1 \times \frac{1}{1.79} \times 1}{646} = 3.48 \times 10^9 \text{ single} = 1.74 \times 10^9 \text{ tandem} \\
1 \text{ tandem} = \frac{6.97 \times 10^9}{1.74 \times 10^9} = 4.01 \text{ singles and not 7.79}
\]

**Combined Load Analysis**

**Findings based on Combined Loads:**

- Tandem Axle is equivalent to 4.01 Single Axles
- Triple Axle is equivalent to 15.4 Single Axles

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**Findings 2**

**Load per Axle resulting in same Detriment as Single Axle:**

- Single Axle: 100% (119 kN)
- Tandem Axle: 84% (100 kN)
- Triple Axle: 73% (86 kN)

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**Findings 3**

**Detrimental Effect compared to Single Axle**

<table>
<thead>
<tr>
<th>Axle</th>
<th>SETRA Peak Stress</th>
<th>Combined Axles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Tandem</td>
<td>12</td>
<td>7.8</td>
</tr>
<tr>
<td>Triple</td>
<td>113</td>
<td>27.2</td>
</tr>
</tbody>
</table>

- SETRA is very conservative towards Tandem and Triple Load Arrangements
- Considering Minimum Stress in calculating Damage gives higher allowable Number
**Closure**

Note: ‘Exercise was carried out for particular pavement structure; results may not be generalized’

However:
1. Results indicate that SETRA is too conservative;
2. Approach can be useful in Design Calculations for aircraft with multiple gear arrangements

Limitations:
- Suitable for f-s-R- Fatigue Relationships
- Joints & Load Transfer (practical limitation)