TESTING OF MULTI PLATE TYPE STRUCTURE UNDER DYNAMIC RAILWAY LOADS

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Abstract

The paper presents results of dynamic load testing of a corrugated steel structure serving as a railway underpass. Acceleration in the backfill and ballast and corrugated steel structure as well as deformations in the corrugated steel were measured. Acceleration gages were installed in the embankment as well as mounted onto the structure. The research was performed under service loads from passenger and freight trains. Maximum speed of the rolling stock was 160 km/h. It was concluded that there’s an important influence of location of the measuring gage (including the depth in the soil) as well as the speed of the trains on measured acceleration values. None of the measurements showed values exceeding maximum allowed acceleration equal to 3.5 m/s².

Key words: corrugated steel structure, dynamic testing, railway structure

1. INTRODUCTION

One of the key issues for railway structures with high speeds is the influence of rolling stock on embankment stability. This issue is important for traditional structures and becomes of crucial concern in the case of corrugated steel structures where the engineering backfill becomes a structural element. Loss of stability of subsoil in standard structures may cause instability of the track, whereas in soil-steel bridges it may lead to loss of load bearing capacity. The measurements soil vibration increase above the corrugated steel structure and of the corrugated steel structure itself were performed in order to estimate the influence of rolling stock traveling with high speeds on soil-steel bridges. The measurements were conducted on a railway underpass located alongside an electrified double track railway route subject to service loads of both passenger and freight trains with speeds up to v =160 km/h.
Presented results have to be considered as preliminary tests that would enable to estimate behavior of the backfill and structures under speeds of 200 – 300 km/h and above.

2. DESCRIPTION OF THE TESTED STRUCTURE

The tested structure is located at w km 432.513 of electrified railway line E20 Warszawa – Kunowice in Poland. The corrugated steel structure that was subject to test is a MULTIPLATE, with 150x50 mm corrugation. The structure is a high profile arch with internal angle of 235°. The structure is placed on concrete foundations.

Basic parameters of the underpass:
- horizontal box clearance: 3.70 m,
- vertical box clearance: 4.01 m,
- bottom length: 17.30 m,
- span of the structure: 5.0 m,
- thickness of the steel wall: 5.0 mm.

Design load in accordance to PN-85/S-10030 for k = +2 (diagram UIC 71).

3. DESCRIPTION OF THE TEST

The amplifier SPIDER8 by HBM serviced by software CATMAN5 was used to measure deformations. Collected data was transferred online directly to computer’s memory. Vertical deformations were measured by induction sensors HBM with the range of +/- 20mm, and accuracy up to 0.01mm. Accelerations were measured with sensors HBM B20, with measurement range up to 200Hz. Accelerations in the soil were measured with sensors MS2005+ by SYSCOM, with measurement range from ±2g and ±4g (g – gravity acceleration) and frequency range 0-150Hz.

Sensors were mounted directly onto the steel structure. They were located alongside the track centerline at the crown. The sensors measuring the accelerations in the ballast and backfill were placed directly in it. Three sensors were placed at the track centerline (over the crown of the structure) and various depths – 80, 140 i 200 m, and one sensor was placed 3 m ahead of the object at 80 cm depth (measuring from the top of the rail) (Figure 1).
Fig. 1. Geometry of tested structure with location of measurement points
Fig. 2 View of tested structure

Fig. 3 View from inside during tests
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Fig. 4 Mounting of sensors in the ballast

Fig. 5 Deformation gages mounted on the steel structure

Fig. 6 Deflection sensor attached to the steel structure

The tests were performed twice. First, frequency and acceleration of vibrations of the steel structure were measured. Second, acceleration of vibrations in the soil and in the structure were measured. Tests were performed twice with regular rolling stock used on the railway line (no special tracks were used).
During the first set of tests measurements for following speeds were performed:
- passenger train – speed 160 km/h,
- passenger train – speed 120 km/h,
- freight train – speed 90 km/h.

During the second set of tests measurements for following speeds were performed:
- passenger train – speed 160 km/h,
- passenger train – speed 100 km/h,
- passenger train – speed 80 km/h,
- freight train – 80 km/h.

4. RESULTS

Maximum values of dynamic deformations were small and were in the range of 0.15-0.22 mm:
- passenger train – v = 160 km/h
  - 0.22 mm
- passenger train – v = 120 km/h
  - 0.19 mm
- passenger train – v = 90 km/h
  - 0.15 mm

<table>
<thead>
<tr>
<th>Type of train (speed)</th>
<th>Measurement point</th>
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<tr>
<td></td>
<td>Measurement in the soil (depth of location)</td>
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<td></td>
<td>Sensors over structure (h – depth from top of the rail)</td>
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<tr>
<td>Freight (80 km/h)</td>
<td>Engine EU 43</td>
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<td></td>
<td>Cars</td>
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<td>Passenger (160 km/h)</td>
<td>Engine EP07</td>
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<td>Passenger (100km/h)</td>
<td>Engine ET22</td>
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<td>Cars-two decks</td>
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<td>Passenger (80 km/h)</td>
<td>Unit EN-57</td>
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Above mentioned results were compared to results of deformations (deflections) during static loads (when structure was taken over to service). Static def-
lections were 0.13 mm on average. By comparing it with results of dynamic load tests generated by identical rolling stock (locomotive of a freight train) we have obtained the following value of dynamic factors ($\phi = \frac{y_{stat}}{y_{dyn}}$): $\phi = 1.15$ ($v=80$ km/h). The results of extreme accelerations were set in tab. 1.

Examples of measured accelerations are presented in figures 7-12.

Fig. 7. Accelerations in point 0 – passenger train V=160 km/h

Fig. 8. Accelerations in point 1 – passenger train V=160 km/h
Fig. 9. Accelerations in point 2 – passenger train V=160 km/h

Fig. 10. Acceleration on steel structure – passenger train V=160 km/h
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Fig. 11. Accelerations in point 0 and in the steel structure – passenger train V=160 km/h

Fig. 12. Accelerations in point 0 – cargo train V=80 km/h
Fig 13. Accelerations in points 2, 3 and in the steel structure with use of a filter to 30Hz – passenger train v=160 km/h

Presented graphs show that each axle of the train generates vibrations of similar characteristics that are strongly suppressed. This confirms current observations of the structure in view of the fact that for tested speeds there’s no loss of stability of the ballast and soil due to dynamic influence of moving trains. By examining changes of acceleration values for various speeds of moving trains one can pose a hypothesis that the behavior of the ballast and backfill will be similar for higher speeds of trains.

5. CONCLUSIONS

1. Main parameters influencing the accelerations of vibrations are speed of the train and its weight. Higher speed and greater weight cause higher acceleration. However, speed is more critical.

2. Increased train speed is followed with increase accelerations. With increase of the speed the influence of the weight of the trains decreases. With a train traveling at speed of 160 km/h the recorded acceleration values were almost the same for the engines (locomotives) and cars. With lower speeds the differences between these two were twice as high.

3. The research indicates that acceleration in vibrations of soil decrease with increased depths (measured from the top of the rail).
4. Measurements at the same depth show that the value of acceleration can be influenced by the presence of corrugated steel structure in the embankment. Generally, accelerations in the backfill measured at the location outside the corrugated steel (ahead of the structure) are lower. The differences decrease with increased speed of the train and with decreased weight of the train. Therefore one can conclude that acceleration in the soil is influenced by the presence of corrugated steel structure, weight of the train and the velocity of the train passing over.

5. The research showed that the values of acceleration of vibrations in the ballast (backfill) and the corrugated steel structure for train traveling with the speed of up to 160 km/h, are much lower than allowed i.e. 3.5 m/s$^2$, therefore there’s no threat to safe service of the backfill stability or comfort of travel.

6. Comparable values of accelerations in the corrugated steel structure and in the backfill at the depth of 2.0 m from the top of the rail allows to pose a hypothesis that with low cover over the structure (ap.1.0 m), the values of acceleration in the backfill and in the corrugated steel structures will be similar and the values of acceleration of vibrations of soil medium away from the soil-steel structure are bigger then those measured in the corrugated steel (fig. 11).

REFERENCES


Streszczenie

Referat przedstawia rezultaty testów z obciążeniem dynamicznym konstrukcji ze stalowej blachy falistej pełniącej rolę przepustu kolejowego. Dokonano pomiarów przyspieszenia w zasypie, balaście oraz konstrukcji ze stalowej blachy falistej, a także odkształceń stalowej blachy falistej. Przyspieszeniomierze zostały zamontowane w nasypie oraz na samej konstrukcji. Badania przeprowadzono w warunkach obciążen użytkowych pociągów pasażerskich i towarowych. Maksymalna prędkość składów wynosiła 160 km/h. Stwierdzono istotny wpływ położenia przyrządów pomiarowych (w tym głębokości w gruncie) oraz szybkości pociągów na zmierzone wartości przyspieszenia. Zadzen z pomiarów nie wykazał wartości przekraczających maksymalne dopuszczalne przyspieszenia wynoszące 3.5 m/s$^2$.

Słowa kluczowe: konstrukcja z falistej blachy stalowej, testy dynamiczne, konstrukcja kolejowe