RESPONSE EVALUATION OF PROTOTYPE NONCOMPOSITE I-BEAM BRIDGE UNDER STATIC LIVE LOAD TEST

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Abstract

In this paper a study is presented on a full scale experimental evaluation and instrumentation of a two lane forty 40 m long simple span bridge comprising of built-up plate girders and rolled girders with noncomposite concrete deck slab having unequal longitudinal stiffness. This field test on actual bridge was required for estimating the true performance of bridge when its behavior was peculiar due to unsymmetrical longitudinal stiffness with noncomposite sections and damaged deck slab under actual boundary conditions. Since lateral distribution of service live load is heavily influenced by longitudinal stiffness of girders, fatigue limit state can severely affect structural integrity by altering lateral load distribution characteristics of the bridge. Such structural behaviors can not be estimated from numerical models due to lack of information of structural interaction within various components. Strains and deflection patterns of various bridge elements recorded under incremental live load (01 to 06 trucks) provided a tool for evaluating the structural response. Experimental evaluation of such bridges provides an insight for potential retrofitting to improve the structural performance of the bridge. The full scale test for experimental evaluation is done by using service live load consisting of six (two-axle) trucks, each weighing 15 metric tons, placed incrementally on one span of Ayub Bridge constructed in late seventies, located at Silk Route also called Karakurum Highway (KKH), carrying major freight traffic between Pakistan and China. The bridge consists of two major exterior plain plate girders with three interior girders of rolled sections. A discussion is presented on the results accrued from the full scale live load test for elaborating the behavior of the noncomposite bridge, which suffered extensive damage over the last twenty five years of its service life under the increasing axle load trend.

INTRODUCTION

Bridges are costly component of a transportation network. For the safety of the public using these structures and for the structural integrity it is vital to evaluate the structural behavior of bridges by conducting a full scale test. Such tests are done in bridges which show signs of distress either in the form of cracks, excessive deflection or any other such indicator. Generally, an expensive task of retrofitting or partial replacement of various bridge components or even in some cases complete removal of bridges can be warranted with confidence by carefully evaluating the bridge under realistic boundary conditions. Field test validate the performance of bridges and may prove to avoid expensive retrofitting, which otherwise would have been decided on the basis of visual inspections. Testing of bridges is a sophisticated job which needs planning, establishing testing methodology and careful interpretation of results to help decision making for a particular bridge.

Ayub Bridge is located on the famous Karakurum Highway (KKH) at Havelian in district Abbottabad, Pakistan. The bridge was constructed in the late seventies by the National Highway Authority (NHA). It is comprised of six contiguous spans of 40meter each having non-composite steel plate girder with Reinforced Concrete (RC) deck slab, see Figure 1. The bridge is located on route, which is carrying major freight traffic between China and Pakistan. The bridge deck suffered severe damage in form of pot holes and had bad expansion joints, see Figure 2. The deck slab in each span had further five divisions, which resulted in six joints in each span. The NHA in its rehabilitation program intended to replace the old deck with a new composite deck slab. NHA asked to conduct a test to record the behavior of the bridge in its original configuration being in distressed state and latter wanted to compare these results with those of another test ,which would be done after rehabilitation works.

Figure 1: Ayub Bridge on Karakurum Highway (KKH – Silk Route), Pakistan

The bridge has six contiguous spans each being 39.800 meters with two Reinforced Concrete (RC) 17.0 meters simple spans at either end of the bridge. Overall width of the bridge was 8.890 meters. The roadway width was 7.366 meters with deck slab thickness of 203mm. Wearing course was 152mm and various layers were overlaid at different stages in the past. Clearance from ground is approximately 10.0 meters. Clearance is measured as average height from soffit of main girder to ground. The overall depth of the two main built up plate girders are 2.438meters, with top and bottom flange width being 826mm and thickness of 54mm, and web thickness of 11.1mm. Six floor beams have a span of 7.320meters which divide the bridge in 5 segments and there is a joint at each floor beam which breaks the continuity of the deck slab. The overall depth of floor beams is 900mm with top and bottom flange width of 304mm and thickness of 16.2mm with a web thickness of 9.6mm.

Figure 2: Pot holes and damaged joints within the 40 meter span

Parallel to the main plate girders are the three stringers of rolled section, each having a span of 7.96meters with depth of 815mm, top and bottom flange width of 225mm having thickness of 22.2mm and web thickness of 14.3mm. The support is metal rocker bearings.

TEST METHODOLOGY

A pre-test site visit was conducted to record geometric parameters of the bridge. During the visit a suitable span out of six was selected for the test. The span was selected on the premise of ease of erecting formwork necessary for the conduct of the test. NHA advised to use maximum of six two-axle trucks each with gross weight of 15 metric tons. The typical two axle Pakistani trucks have legally allowed gross weight of 17.5 tons, whereas due to overloading, this truck can have gross weight as high as 22 to 23 tons. For this truck maximum permissible axle load is 12 tons, whereas due to overloading the axle load can be as high as 17tons. The spacing between the front and rare axles is 4.42meters and axle width is 1.83meters. For conducting the test a numerical model of one span of the bridge was prepared in which material properties were assumed. Critical loading positions that could give the maximum response of the bridge were determined for incremental loading of the two – axle 15ton trucks. It was decided to record the response parameters of the bridge for incremental loading from one truck to six trucks and incremental unloading. The response parameters at mid span were recorded, which comprised of deflections and strains of the deck slab, main plate girders, stringers and floor beams. Total of 20 electric resistance based strains gages utilizing quarter Wheatstone bridge and 12 displacement transducers were used and data logger was set to least count of 0.001mm for deflection and 1με (1 micro strain) for strains. All the dimensions are in millimeters unless otherwise specified.

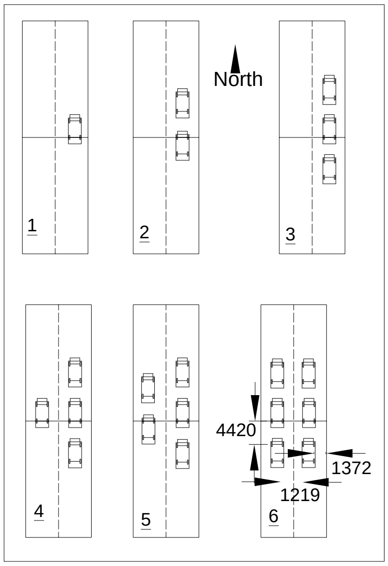

Figure 3: Incremental loading and unloading sequence of six 2 – axle trucks

The loading position of the front and rare axle for various combinations of trucks were marked on the bridge deck. The scheme of loading and unloading was given to a engineer responsible for placement of trucks. Figure 3 shows the details of incremental loading and un-loading of six trucks. The bridge plan showing the details of the instrumentation is presented in Figure 4, whereas in Figure 5 cross sections of girders are shown for the installed instruments.

CONDUCTING THE TEST

After completion of all markings, instrumentation and final checking of the instruments installed; the bridge was closed for all sorts of traffic including pedestrians. A pause of five minutes was given for achieving the steady state of bridge and the data logger unit was initialized and the first truck was brought to position 1 as shown in Figure 3. After precise positioning of the truck at position 1 all the staff evacuated the bridge deck. After waiting for five minutes, first set of readings for deflections and strains were recorded. Then a second truck was brought and position 2 was organized as shown in Figure 3; after waiting for five minutes a second set of readings was recorded. The cycle went on till all the six trucks were loaded as per position 6 of Figure 3; same process can be seen in Figure 6. Unloading started in the same fashion but now in reverse order till fully unloaded. The final sets of reading was taken for no trucks on the bridge deck after five minutes of pause when the last truck left the bridge. It is important to note that the distance between the two trucks (i.e. distance between rear axle of leading truck to the front axle of trailing truck) was kept 4,420mm, for reasons of simplification of placement of trucks on the bridge deck. See Figure 7 showing the three trucks loaded on to the bridge.

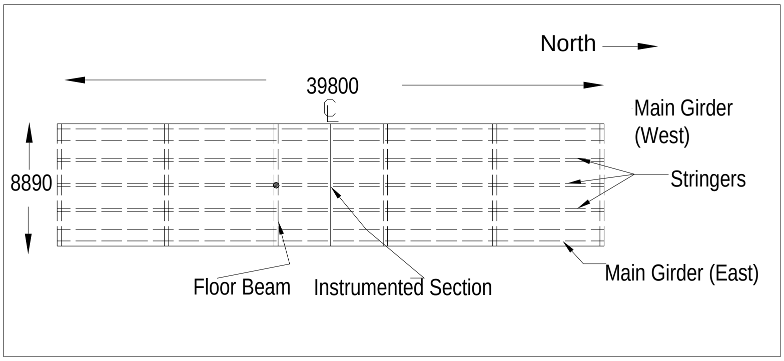

Figure 4: A single simple span having five segments with instrumentation on midspan

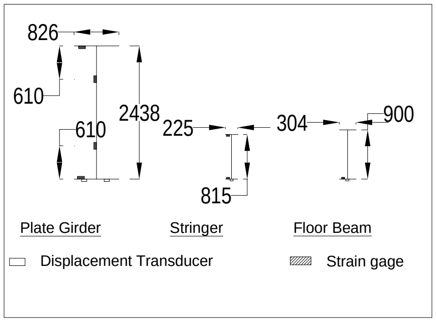

Figure 5: Cross section of girders showing installation of strain gages and displacement transducer at bottom flange

RESULTS OF STATIC LIVE LOAD TEST

The data was recorded for every load case as shown in Figure 3. For each loading case, five sets of readings were taken whose mean was used. 1950 data points were recorded for complete test of loading and unloading of six trucks. Refer to Figure 8 for midspan deflections of both main plate girders. Maximum deflection of 14.939mm is observed in West plate girder, whereas 14.129mm in East plate girder. Average deflection per truck is 2.685mm, average permanent set of 1.997mm in the plate girders is believed to be contributed by settlement of working platform due to the movement of team members above the platform.

In Figure 9 deflection curve for the three stringers is plotted. Maximum deflection of 17.204mm is observed for the Interior stringer, whereas the deflection of 11.263mm is observed for the East stinger and deflection of West stringer is recorded as 15.997mm, for the six loaded trucks. Average permanent set of 1.689mm is considered to be contributed by the platform settlement.

Refer to Figure 10 for midspan deflection of exterior concrete panels. West exterior concrete deck panel deflects 16.149mm, whereas East exterior deck panel deflects a maximum of 13.007mm. Average 1.802mm deflection is potentially contributed by the platform settlement. However, 87.6% elastic recovery is still observed.

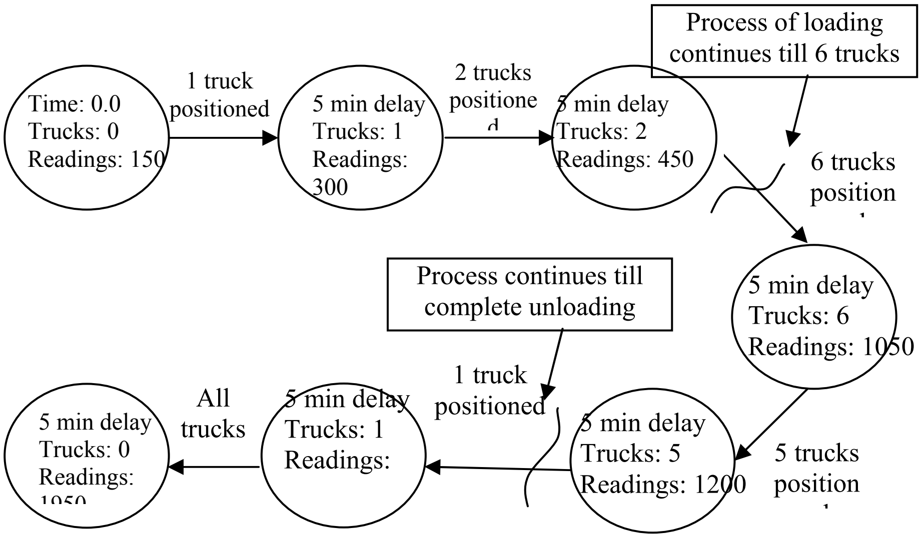

Figure 6: Incremental loading and unloading cycle for six trucks

Refer to Figure 11 for deflections of the two interior RC deck panels. The maximum deflection of 15.552mm is observed for the West interior deck panel and 12.966mm deflection for East Interior deck panel. An average 1.256mm of permanent set probably due to platform settlement is observed.

Figure 7: Three trucks loaded on the bridge

Refer to Figure 12 for deflection profile of cross-section incrementally loaded and unloaded. Absolute maximum deflection of 17.204mm occurs at the midspan of interior stringer. From the figure, it can be observed that West plate girder deflects more than East plate girder, similarly West exterior deck panel and West exterior stringer experience more deflection than corresponding counterparts on the Eastern parts of the bridge, despite the fact that loading of the six trucks is concentrated on the Eastern side of the bridge, as shown in Figure 3. Since trucks are positioned near the East plate girder, more deflection is expected in the Eastern components rather than the Western components of the bridge. An explanation behind this peculiar behavior can be attributed to the loss of contact between concrete deck panel and girders which reduce the longitudinal stiffness on the Western side of the bridge, thereby showing more deflection as compared to Eastern side of the bridge. Damaged bridge deck on the West side can be seen in Figure 2.

Figure 13 shows the strain profile of the East plate girder under loading and unloading. Maximum bottom flange strain of +150.2με (micro strain) is recorded, whereas -62.8με is recorded in the top compression flange (+ sign is tensile strain & - sign is compression). Main plate girders tend to exhibit some restraint, offered at the top flange due to friction between deck and surface of the flange. The amount of strain recorded for six trucks shows that strain range is considerably well within the linear elastic range. Due to limitation of space in this paper, only one case of strain profile is presented here.

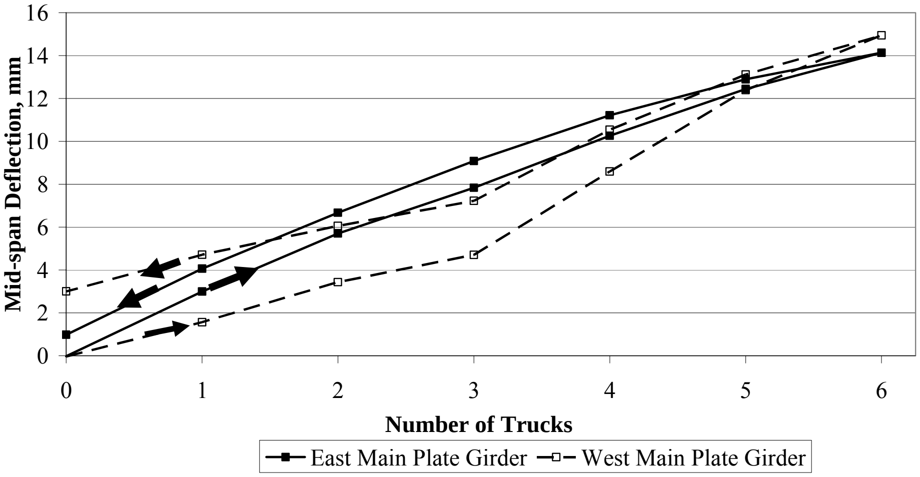

Figure 8: Midspan deflections of main plate girders for loading and unloading

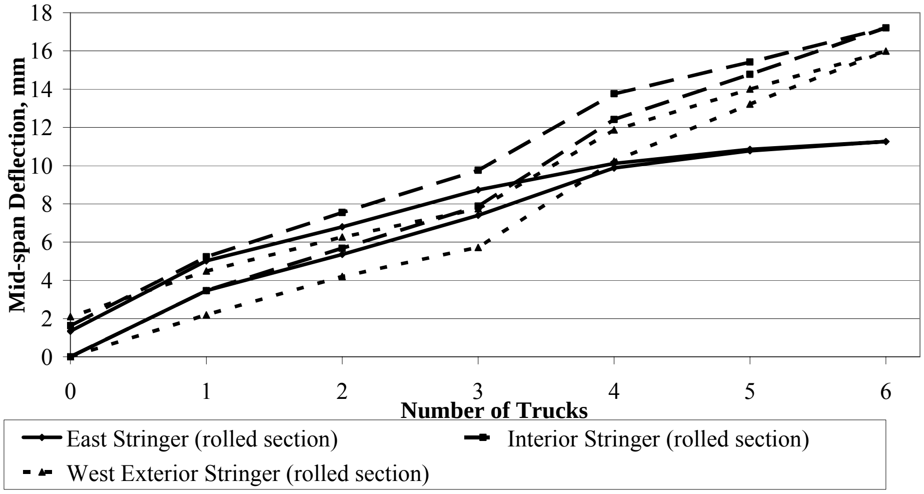

Figure 9: Midspan deflection of stringers for loading and unloading cycles

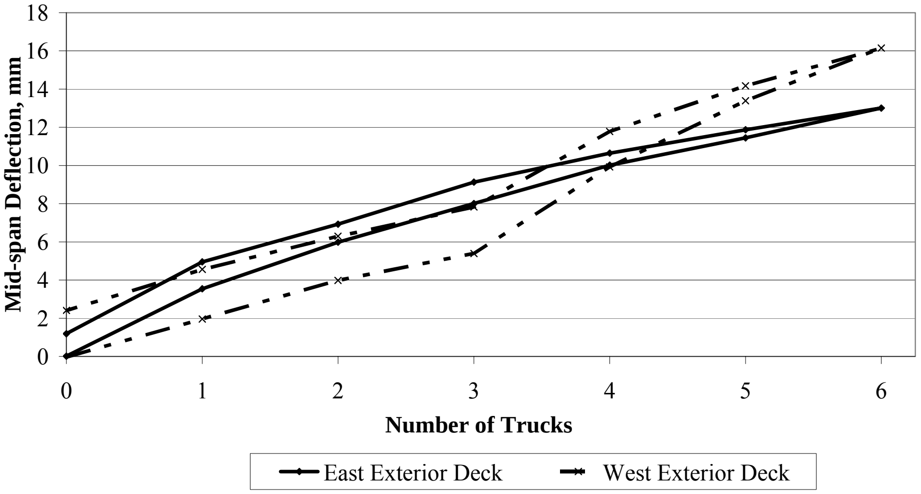

Figure 10: Midspan deflection of exterior concrete deck slab panels for loading and unloading cycles

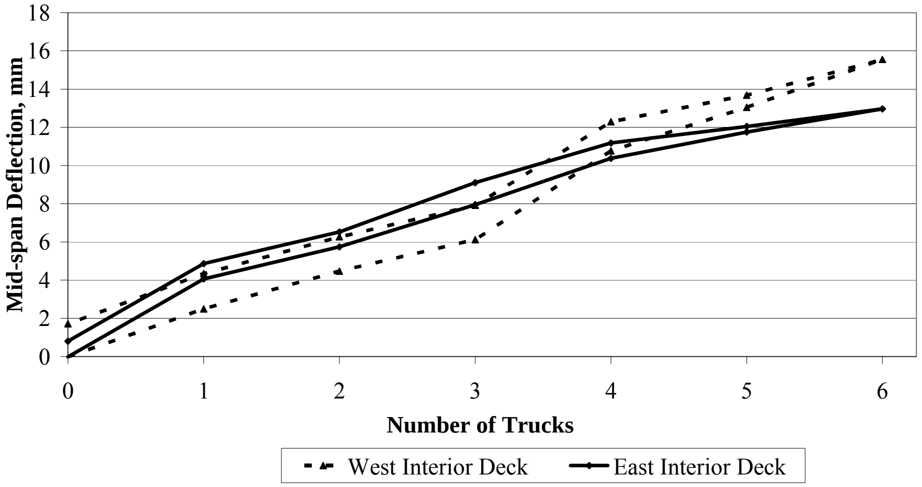

Figure 11: Deflection of interior concrete deck slab panels

CONCLUSIONS

Noncomposite bridges with unequal longitudinal stiffness can exhibit peculiar behavior under service loading. Unequal longitudinal stiffness has a great influence on transverse load distribution characteristics of the bridge. Noncomposite sections further complicate the behavior at the expense of reducing longitudinal stiffness, resulting in high relative deflections among members that otherwise would have been considerably less. Under repeated loading of trucks with unsymmetrical deflection pattern of a bridge system over the years, causes damage to deck slab, which further disturbs the load transfer path. The field tests using typical trucks for loading and using deflection transducers and strain gages for recording the bridge response; it is observed that in these types of bridges, even when the stresses in main girders are not significant as seen from the load test results, the unequal longitudinal stiffness cause excessive deflection in some members, which in turn can cause damage to deck panels thereby compromising the overall performance of the bridge system. The structural behavior of such deficient bridges can only be ascertained by conducting field load tests as presented in this paper ,which reveals important information with regard to their structural behavior. Such studies can be extremely helpful for suggesting retrofitting measure and comparing the performance of the bridge under retrofitted condition. Making such bridge system composite can improve the load distribution and overall performance of the bridge system.

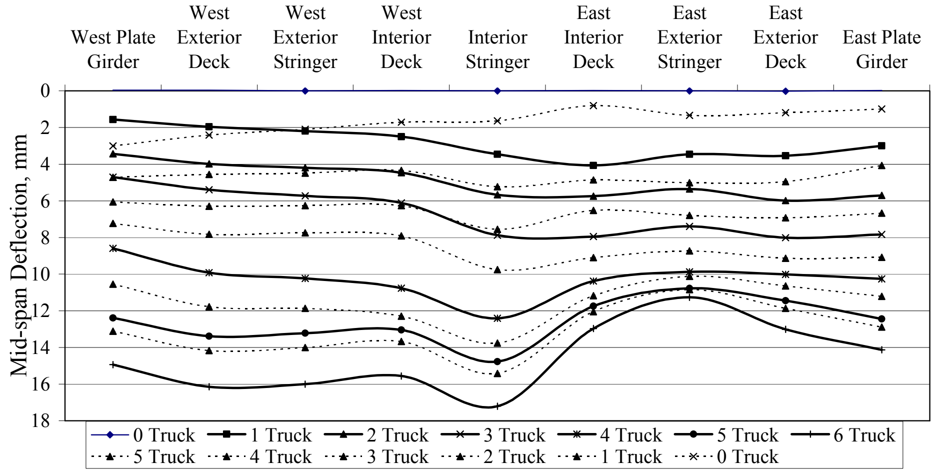

Figure 12: Midspan deflection profile of cross Section for loading and unloading

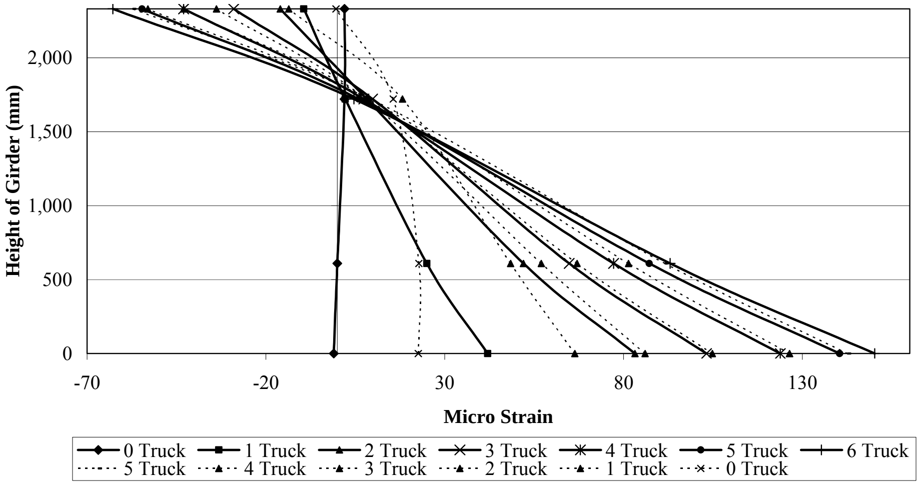

Figure 13: Strain profile of east main plate girder under incremental loading and unloading of six trucks

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