Noiseless In-Place Removing Using Induction Heating System of Asphalt Layer Bonded with Steel Deck Bridge

H.Y. Yoon, Gomi A. & Hosokawa H.
Green ARM Co., Ltd., Chiyoda-ku, Tokyo, Japan

ABSTRACT: Repair work of steel deck bridges for the safety has to use the chipping methodology now, which manually breaks with a breaker existing asphalt mixture layers consisted of asphalt concrete and Guss-asphalt, and removes them. Work is done usually at night under a traffic control to minimize inconvenience to transportation, which, however, inevitably causes breaking noises and dust problems, and is also likely to damage fished joints and bolts placed on steel deck surface. There have been interrupted night works by complaints against work noises at night coming from residents nearby and a good alternative for the conventional methodology has been needed. A new innovative technology invented uses induction heating, which generates induced current on a steel deck penetrating the asphalt mixture layers and directly heats the deck plate, and dissolves the contact face of Guss-asphalt layer bonded with the deck plate. Thus the bond strength gets weakened and the asphalt layer comes to be smoothly removed. It has been proven through actual site work that the contact face of Guss-asphalt layer alone gets dissolved and that very smooth separation and removal of the asphalt layers from the steel deck done without damaging the deck. Noise reduction by 20 to 40 dB is also conspicuous compared with the conventional manual work. The paper reports that the invented technology is able to do asphalt mixture layer removal work neither generating breaking noises nor causing vibration and thus able to much improve both work process and efficiency, which shortens work schedules and saves cost.

KEY WORDS: Induction heating, Magnetic field, Steel deck plate, Splice plate, Wedge bucket.

1 INTRODUCTION

It is the present state of asphalt layer removing method that manpower using a jackhammer breaks asphalt layer and removes it from a steel deck plate. Removal work with a jackhammer inevitably generates violent noises and dusts, and can not eliminate a possibility to damage a splice plate and bolts fixed on the surface of a steel deck plate. Asphalt removal work is to be carried out at night of low traffic volume, which would cause minimum inconveniences to the transportation. The work has been forcefully suspended in a few cases by adjacent residents' claims against noises during night work and the work manner is required to be amended. In order to solve the issues IHIR (Induction Heating In-place Removing) work method (Patent No.: 4330639), which applies induction-heating technology and removes bonded asphalt layer from the surface of a steel deck plate efficiently and noiselessly, has been developed for an actual use and proven as effective and successful.

2 OUTLINE OF IHIR (Induction Heating In-place Removing) WORK METHOD

An induction heating equipment generates a magnetic field through the asphalt layer from above its surface onto the steel deck plate and induction current gets generated within the steel deck plate. Then the plate gets inducted current (eddy current) generated inside of it and generates heat (Figure 1). The bottom face of asphalt layer, which faces the bonded contact face between the asphalt layer and the steel deck plate, gets softened and the bonding force gets weakened. Asphalt layer is removed with a removing wedge device inserted into the interface while the bonding force remains weakened. Removing work can be easily done because the bonding force at any part of the plate including structurally complicated parts gets weakened and removing work can be done without damaging the steel deck plate. Compared with the conventional work method noise reduction is obvious and, noiseless and tremor-less work can be done at night. Workers can be released from extremely hard work including jackhammer work and smaller number of workers can do the required work.

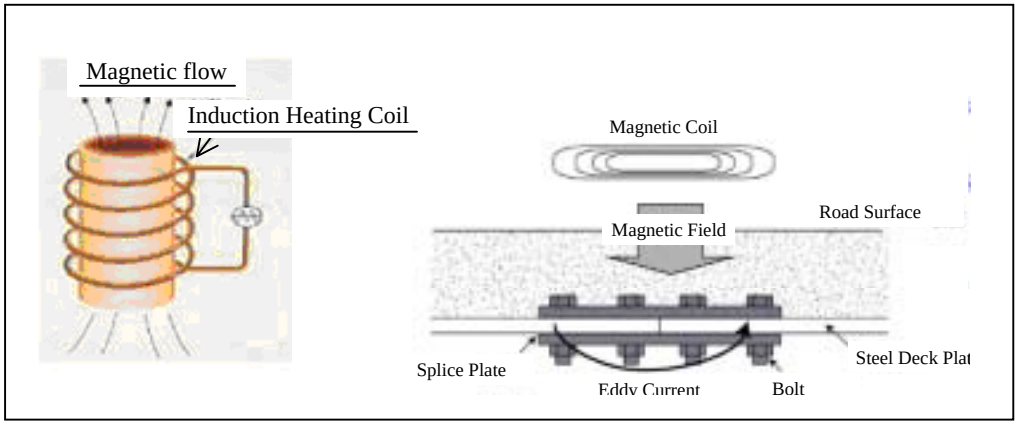

Figure1: Induction Heating Principle.

3 HEATING MACHINE & PARTS OF THE MACHINE

Photo 1 is the IHIR machine developed and put in actual use, which is being carried on a regular truck. The machine consists of a heating equipment, a power vehicle which consists of a generator, a cooling water circulation equipment, a control unit and a bucket for removing asphalt layer. A heating equipment has pieces of panels where magnetic coils are built in to generate induction current within a steel deck plate to get heated, which is shown in Photo 2. Each panel is 1,400 mm in length x 700 mm in width and about 50kg. 5 pieces of heating panels are used to rightly meet with the usual road width. A power vehicle is equipped with a cooling water circulation pump for cooling of magnetic coils and power cables. The bonding strength of asphalt with a steel deck plate surface gets weakened through induced current's heating of the surface, which dissolves the bonded contact face. Photo 3 shows a usual shovel is inserted beneath the asphalt layer and strip it off for removal. The shovel is equipped with a wedge bucket rather than a usual bucket.

Photo 1: Induction Heating Machine (Front View) Photo 2: Induction Heating Panel

Photo 3: Removal Scene

4 FUNCTION CONFIRMATION TEST

As a test yard asphalt layer paved on a steel deck plate was prepared.
The followings were confirmed through a function confirmation test;

① Extent of injury by striping on a steel deck plate,
② Work noise level,
③ Quality of work done for specific parts, including striping work at a splice plate,
④ Influenced range by heating including a degree of influence on an adjacent lane.

Photo 4: Test Construction Scene

Photo 4 shows a test operation which was done for 15 square meters under a targeted temperature higher than 60 degrees Celsius at the plate surface.

It was confirmed that asphalt layer can be easily removed from a steel deck plate by a removing device because bonding strength at the contact face between them gets weakened when induced current gets generated within the plate to be heated accordingly, which softens the bonded contact face.

And the followings were confirmed;

① Asphalt layer was removed from the steel deck plate as a large piece of plate and no injury was given to the plate.

② Noises generated through the IHIR work process were mainly due to the generator's work and a wedge bucket's contact with the steel deck plate, but no noise was generated from striping work. A noise level at a place 1.0 m to 1.5 m separated from the removal work place was 73.9 to 76.7 dB(A), which is to be appreciated as a low noise work method.

③ It was successfully done to clearly remove asphalt layer from the plate with bolts used at a splice plate, which is structurally intricate for the striping work.

④ It was feared that the bonding strength of asphalt layer with the plate might be weakened at adjacent places beyond the work site through heat generation caused by induced current but as is shown in Figure 2 temperature of the steel deck plate decreased sharply in accordance with a distance from the induction heating panel. At a place 10 cm separated from the edge of the work site the temperature increase was about 25 degrees Celsius, of which influence is considered to be negligible. In actual work a groove 20 mm to 30 mm deep is also made by a cutter along a work line for the work edge separation, which eliminates any influence on adjacent places coming from asphalt removal.

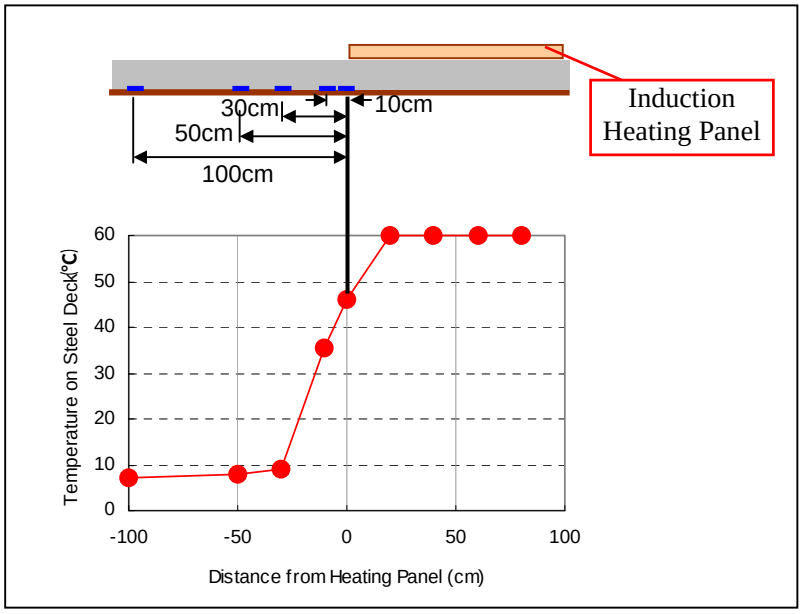

Figure 2: Effects on Adjoining Road

5 CONFIRMATION THROUGH ACTUAL WORK

5.1 Influences on Communication Cables and A Human Body by A Magnetic Field Made by Induction Heating

An evaluation was done of influence on JR (JAPAN RAILWAY) overhead electric wires and communication cables by magnetic field made by induction current at the work site on the

bridge over the JR railways at the Shinjuku Station South Exit on the Koshu Street of the National Route 20 in Tokyo. JR-East offered the job. The evaluation was done by an analytical simulation instead of actual measurement of induced current, which needs a large scale preparation and is expensive (Figure 3 and Figure 4). CISPR (the International Special Committee on Radio Interference) Publication sets the allowable electric field strength at 0.0032 m/V at a distance of 30 m from the point of 150 to 490 kHz in terms of inverter frequency. The induction heating system of the IHIR uses 35 kHz, which falls within very low frequency range and is not at a harmful level, and thus there is no corresponding regulation.

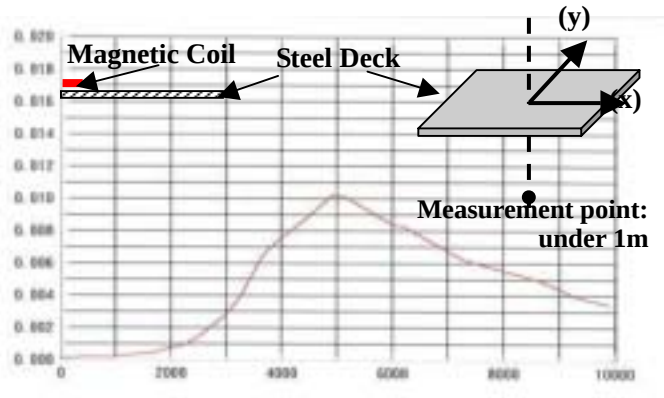

Figure 3: Magnetic Field Strength (x)

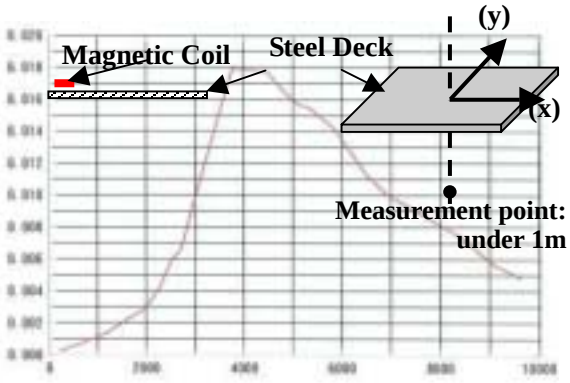

Figure 4: Magnetic Field Strength (y)

Figure 3 and Figure 4 respectively show simulation results of distribution of magnetic field strength in a direction of X and Y 1m below a steel deck plate. The magnetic strength in a direction of X right under a steel deck plate is almost 0V/m and at its peak about 0.011 V/m at the point 450 cm separated from the plate. Along Y axis likewise almost 0V/m was right under the steel deck plate and at its peak about 0.018 V/m was at the point 400 cm separate from the plate. Therefore it was confirmed that there is no influence on overhead electric wires and communication cables 1m under the plate of induction heating adopted by IHIR. Table 1 shows magnetic field strength of electric devices in general, which shows the magnetic field strength of IHIR is much lower.

Table 1: Field Intensity of Generic Electric Equipment

Machine Model	Distance	Magnetic Field Strength (V/m)
Automatic Washing Machine	Front Side	15
IH Cooking Heater	10cm from Front Side (Fire Power: Medium Heat)	97.9
Microwave Oven	50cm from Body	500
Tube Television	50cm from TV Screen	250
Induction Heating Equipment	**80cm from Coil**	**86**

Figure 5 shows induction heating values measured by a portable measuring instrument, which is to be used to evaluate influences on a human body as well as JR overhead electric wires and communication cables of a magnetic field generated by a induction heating panel.

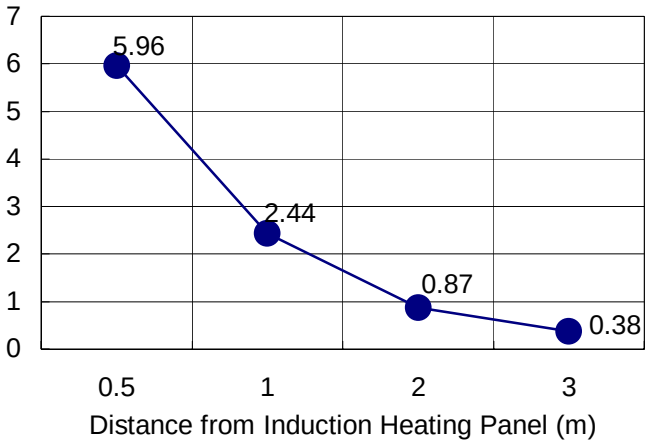

Figure 5: Results of Electromagnetic Wave Measurement

Photo 5: Measurement Scene & Measurement Equipment

The guideline of ICNIRP (International Commission on Non-Ionizing Radiation Protection), that is the maximum limit on exposure to several kinds of NIR (Non-Ionized Protection) is 6.25. An operator of the IHIR machine worked being located at a place more than 0.6 m away from the induction heating panel and it was judged that there was no safety question as is shown in Figure 5.

5.2 Pavement Thickness vs. Heating and Work Efficiency

It is assumed that pavement thickness varies from place to place. Coils of an induction heating panel are designed so as to generate 100% of its heating capacity at 80 d-mm, which means the distance between induction heating coils and a steel deck plate almost equal to pavement thickness. Figure 6 shows correlations between plate surface temperature and heating time depending on the distance. An influence on heating efficiency of pavement thickness was confirmed at the work site of the bridge over Lake Kawaguchi offered by the Yamanashi Prefecture local authorities. Under the ambient temperature of 15 degrees Celsius in early November 2008 induction heating efficiency was about 10 to 15 degrees per minute and work efficiency was about 30 square meters per hour at night work over the bridge.

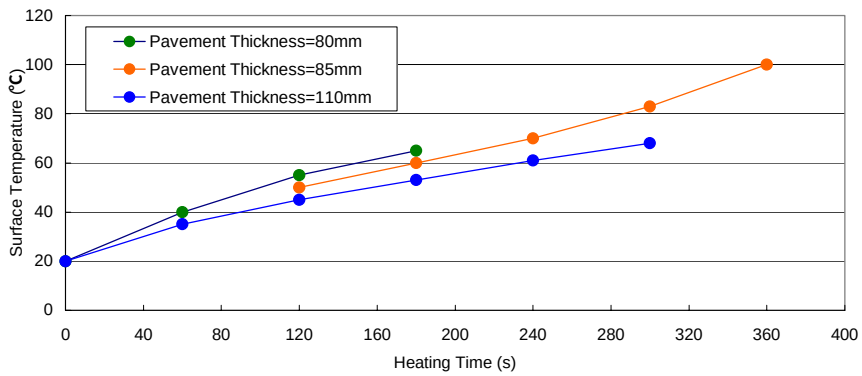

Figure 6: Heating Time & Temperature of Steel Deck Plate

The IHIR method was adopted for a repair work of the Kangetsu Kyo Yoko-Oji Municipal road (Momoyama Flyover Bridge) because residential areas are nearby and work noise had to be controlled. Pavement thickness had been increased by repeated overlays and highly varied from place to place. The work had to be done under such conditions. Therefore before the IHIR removal work started the existing pavement 200 mm thick was cut off by a cutting machine. Table 2 shows worked areas of different pavement thickness and corresponding work efficiency.

Table2: Work Efficiency

Operation Area (m^2)	Pavement Thickness (mm)	Working Efficiency (m^2/h)
281.2	100~120	43.3
	100~110	46.9
	110~120	37.5
	80~85	51.1

d-mm becomes longer in accordance with pavement thickness and heating efficiency decreases accordingly as mentioned above. Whereas the work efficiency was about 38 to 45 square meters per hour when pavement thickness was 100 mm to 120 mm, 51.1 square meters per hour were achieved as the usual work efficiency with the targeted thickness of 80 mm or so, which was more efficient by 13 to 34 % compared with the case of 100mm to 120mm thickness. As a peak figure of short time duration (3 to 5 minutes) 90 square meters per hour maximum were achieved. However, 40 to 50 square meters per hour would be appropriate work efficiency because more volume of removed asphalt pieces would otherwise have to be carried away at once, which would lower work efficiency.

5.3 Work Noise Level

It is the biggest merit that the IHIR method generates extremely low work noise. The noise comes only from work noise of the generator and of a wedge bucket to remove asphalt layer. Figure 7 shows the comparison of noises generated by the IHIR method and the conventional one. Compared with the conventional method using a jackhammer it was confirmed that the noise level of the IHIR method was lower by about 20 dB measured on the bridge and lower by 40 dB under the bridge, which was that environmentally friendly.

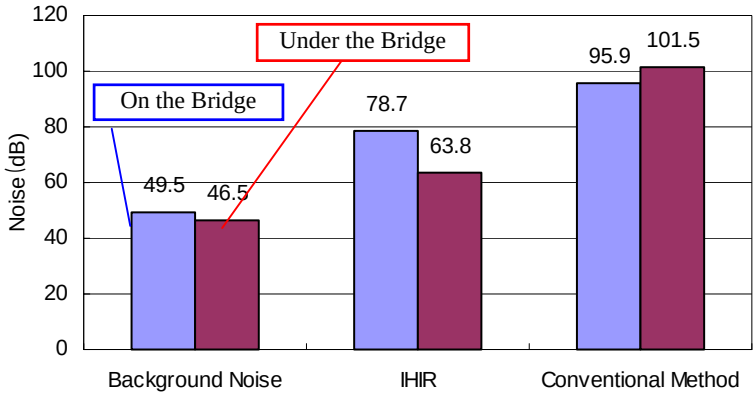

Figure 7: Results of Noise Measurement

Another noise measurement was done with the repair work on National Route 43 in Kobe Municipal city, Hyogo Prefecture (Iwaya Highway Bridge) which was offered by the Ministry of Land, Infrastructure and Transport. The Government of Japan had lost a lawsuit on work noise at the site and a special care had to be paid to a work noise level there. Under the circumstances the conventional method was not possible using a jackhammer which can not avoid generating violent work noise and the IHIR was adopted by a proposal of a contractor. Whereas the ambient noise level on the side street under the highway was 68.5 dB, the noise level under the highway of the work was 66 to 78 dB, which was low enough being comparable to such levels as those of lobbies of theaters and banks, and no complaint was brought about.

5.4 Heating Time and Workable Hours

Heating and temperature changes over time after heating were measured at the above mentioned work site of Iwaya Highway Bridge, which is shown in Figure 8.

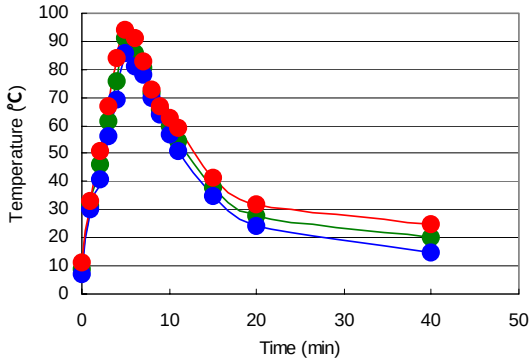

Figure 8: Heating Temperature Rise & Time-Decrease in Temperature

Temperature increase rate through heating was 15 degrees Celsius per minute with pavement thickness of 90 mm, which is almost equal to the data at Lake Kawaguchi Bridge, which is shown in Figure 6. The minimum allowable temperature for removing asphalt layer is set at 60 degrees Celsius as the standard, which is based on the past test work results. A certain temperature decrease takes place during the time lag between the timing when temperature reaches the peak right after induction heating coils pass the point and the timing when a wedge bucket inserts and removes, which is 0 to maximum 2 to 3 minutes. As a result of measurement under ambient temperature below 10 degrees Celsius as working conditions it took 5 minutes for the temperature to decrease from the peak temperature of about 90 degrees Celsius to 60 degrees Celsius which is minimum temperature required for the removal work.
Therefore it is considered that the IHIR removal work has to be done within 5 minutes and it has been confirmed that the work should be able to be done enough within the time allowance. As a footnote there is a case where the time lag was longer than 5 minutes and the removal work was successfully done with the bonding strength below asphalt pavement remained weakened.

5.5 Workability at Splice Plate of Projections

Photo 6 and Photo 7 show removal work done with a splice plate at the work site near to Yamada-Gawa Interchange on the KEINAWA Expressway (Keiji Bypass Sagara Highway Bridge), which was offered by West NEXCO.

Photo 6: Removal Scene (Sufficient Heating)

Photo 7: Asphalt Mixture Removed

Photo 8: Removal Scene (Insufficient Heating)

There is a possibility that some remains may be left behind sticking to bolts in case an asphalt layer can not get removed as a large piece but rather gets broken into small pieces when stripped where there exist a splice plate of projections bonded with heavily aged asphalt. In such a case the work speed of heating panel gets lowered and heating time increases with the machine speed set at 0.15 to 0.2 meters per minute. Photo 6 and Photo 7 show that perfect removal work was done. In a similar case but without a splice plate of projections perfect removal work was done at the speed of 0.3 to 0.4 meters per minute.

6 CONCLUSION

The IHIR method has been officially evaluated as the patented technology and method as mentioned in the below reference that can remove asphalt layer bonded with a steel deck plate without damaging the plate, a splice plate and fixed bolts, and also work at a very low noise level. The method enables to extend removal work hours to deep night and has been highly appreciated by the job authorities. The Asahi dated November 4th, 2009 reported with respect to bridges in Japan “There are unexpectedly fast aged and corroded concrete and steel decks which have been used. 121 road bridges in the country have been identified as almost collapsed and 680 are under the strict control of vehicle weight prohibiting heavy traffics.

Actions for urgent safety checks and measures are needed". The IHIR method will be more needed for such maintenance and checks.

Finally the authors express their sincere gratitude to Mr. Tanioka of Metropolitan Highway Co., Ltd., Mr. Oniwa of SHUTOKO Maintenance East Tokyo Co., Ltd., JR-East (EAST JAPAN RAILWAY COMPANY), and Ibaraki Administration Bureau, Kansai Office, West Nippon Expressway Company Ltd. for opportunities for commercialization of the method they kindly offered and for their useful advice for better site work, safety management and technology improvement. The authors are also thankful to Mr. Harakawa of Takenaka Research & Development Institute, KAJIMAROAD CO., Ltd., NIPPO CORPORATION, OBAYASHI ROAD CORPORATION, TAKENAKA Road Construction Co., Ltd. who are the members of the co-research group to promote the commercialization of the method.

REFERENCES

Patent information as follows

NATIONAL PATENT;

- PATENT NUMBER: No. 4330639
- CONPLETION DAY: June 26, 2009
- PATENTEE: Takenaka Corporation, TAKENAKA Road Construction Co., LTD.
  Green ARM Co., Ltd.
- TITLE OF INVENTION: Asphalt Pavement Removal Method, Asphalt Pavement Removal System, Electromagnetic Induction Coil Unit, Electromagnetic Induction Equipment, Lift off Procedure of Asphalt Pavement

PATENT pending abroad based on PCT application.