Correction Problem of Pavement Evaluation with FWD Deflection

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ABSTRACT: The asphalt pavement with bounded base works linear elastically under FWD impact load 40～60kN. Different pavement has different contact pressure even though the same height of FWD falling weight, and the difference can be more than 10% at the center of the load plate. The regressive relation between the deflections under standard (50KN) and the other load was established. The statistic formula was also given for the transfer between FWD and Benkelman Beam deflection in Jilin province.

KEY WORDS: FWD, deflection contrast, deflection transfer, Benkelman Beam.

1 INTRODUCTION

Deflection automatic checkout equipments used in the world are mainly Falling Weight Deflectometer which is called FWD for short. American and many European countries also have established relevant evaluating standards and calibration center (Feng, Tang and Li, 1996, Zeng, Zhang and Cheng, 2001). Now China has introduced forty sets of FWD, and has done many determinations and research work. In the current JTJ059-95 (Field Test Methods of Subgrade and Pavement for Highway Engineering), FWD has been listed in deflection checkout equipments. But because of the lack of design standard and construction checking standard in accordance with FWD, the measured deflection values must be convert to deflection values of Benkelman Beam. So, the research about the relationship between FWD and deflection measurement with Benkelman Beam must be accelerated.

The existing theory analysis and research achievements indicate that they have good linear relationship (Song, He and Feng, 2000, Tang, Deng and Li, 1990, Tholen, Zeng, Zhang and Cheng, 2001). Although there are conversion equations of contrast tests in the references, the regression coefficients in the equations are usually different among the pavement structures, so it leads many inconveniences when using. In using process, the pavement structures having different rigidities have different responding when they support the same lashed load, that is, for pavement structures having different rigidities, the contact pressure which are pressured to the pavements are different, even the heights of the FWD falling weight are the same. There are two ways to solve this question: one is adjusting the height of the FWD falling weight frequently; the other is finding a regularity to correct the deflections. Although the former is simple, it is hard to obtain identical contact pressure when operating. So it is necessary to establish deflection calculating formulas under different contact pressure.

2 THE DEVIATION OF DEFLECTION CONTACT PRESSURE

This paper has done contract test researches about the deviation of contact pressure and deflections using phonix PRI2100 FWD. Table1 gives the contact pressure of the asphalt pavements with bounded base of different grades under the same surveying temperature and height of the FWD falling weight. If using 50kN as characteristic load or the maximal load in the same section, there are many points that the load errors of which exceed 5%, a few of points even exceed 10%. This illustrates that when evaluating deflections, if the measured deflections are not converted to under the same characteristic load, it will lead to wrong evaluating result. Except the roads like ChangYu highway, the structure rigidities of which are well-distributed, its deviation is negligible. For many roads in service, because the pavement rigidities have great dispersity, the deviation can not be neglected.

Table1: Load and deflections at the same height of FWD falling weight

route	Test section（m）	Deflection scope in the center（μm）	Scope of contact pressure（kPa）	Scope of lashed loads（kN）	Ratio that the deviation exceeds 5% in regard to 50kN/the maximal deviation（%）	Ratio that the deviation exceeds 5% in regard to the maximal load in the same section/ the maximal deviation（%）	Height of FWD falling weight（mm）	Measured temperature
Changchun-Fuyu Highway	K101+599～K102+003	83～99	694～703	48．98～49．68	0/-2.04	0/1.43	140	Air temperature20 ℃ Surface 20 ℃ Inside 21 ℃
Changbai western route	K12+000～K12+802	180～597	712～797	50.32～56.34	53.3/12.68	73.3/11.96	170	Air temperature 28 ℃ Surface 27 ℃ Inside 20 ℃
Highway aroud Changchun	K144+898～K145+846	76～140	680～733	48.09～51.84	0/-3.82	55.00/7.79	120	Air temperature 33 ℃ Surface 28 ℃ Inside 29 ℃
Helong town-Shaoguo town	K3+300～K3+454	2030～3723	633～667	45.09～47.14	100/-10.46	50.00/5.29	170	Air temperature 33 ℃ Surface 31 ℃ Inside 29 ℃

3 THE LOAD CORRECTION FORMULA OF DEFLECTION

In order to determine the relationship between load and deflection (basins), this paper has done four-grade load application test on the points of the roads in table1, the load is between 40 kN and 60 kN. This paper illustrates the relationship between load and deflection, taking four points the linear relationship of which are worst, Figure1 and table2 give the concrete condition. Initial analysis indicates that for the same point, the deflection values of the deflection basins rise accompanying the raising of the load grade, in the same surveying temperature and the scope of common used loads, but the increasing range decreases accompanying the distance between the point and the center of load increasing. It also indicates that in the scope of common used loads, the relationship between the deflection values and load is approximately linear, which illustrates that the pavement structure is in elastic working scope.

If assuming that the relationship between the deflection value and the load is linear in the scope from 0-grade load to common used loads (it is approximately linear in reference Garg and H.Marsey, 2002), then we can use the straight line crossing 0 point to describe it. Doing unitary linear regression ($D_{FWD}=\alpha+\beta\cdot P$), the related coefficients exceed 0.98, the significance tests are that $r>r_{\alpha=0.01}=0.959$, $F>F_{\alpha=0.01}=34.1$, they are all fairly relevant. Table2 gives the related analysis result of the points, the related coefficients of which are worst in Changnong K6+450.

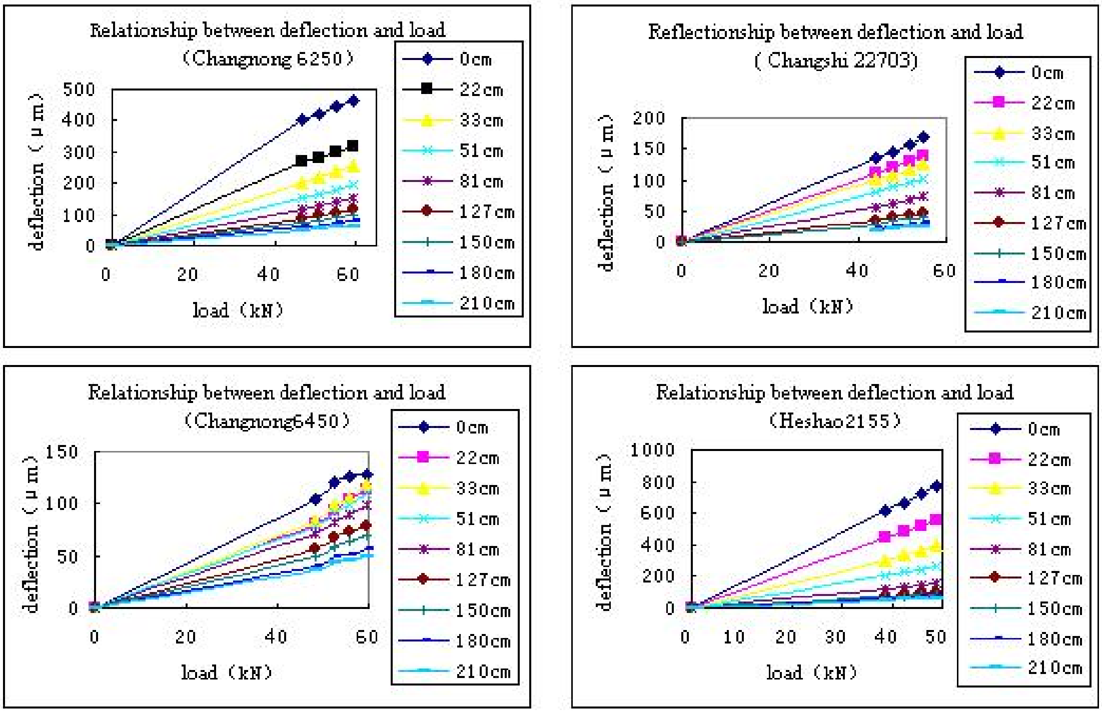

Figure1: Relationship between deflection and load after enforcing 0-grade load

Table2: The regression result of deflection and load after exerting 0-load (regression equation: $D_{FWD}=\alpha+\beta\cdot P$)

Pile number	Position (cm)	Regression coefficient a	Regression coefficient b	Related coefficient R	Significance test F	Relative error without α (%)
Changnong6450	0	0.1619	2.2060	0.9918	725	0.2
	22	-1.3747	1.8486	0.9804	301	1.6
	33	-1.2284	0.9100	0.9851	598	1.4
	51	-1.1887	1.7796	0.9842	374	1.5
	81	-0.9289	1.5944	0.9864	437	1.3
	127	-0.8148	1.2948	0.9844	381	1.4
	150	-0.7726	1.1412	0.9826	339	1.5
	180	-0.5602	0.9329	0.9841	372	1.4
	210	-0.3882	0.8226	0.9907	639	1.0

The deflections of points in the same radius between pavements of different rigidities differ greatly, so it is impossible to establish deflection-load relation formula with the same coefficients. But analysis also indicates that in the relationship established between deflection and load, the constant term coefficients are so small (μm grade), with the relative errors not exceeding 2%. So, we can consider establishing the relationship as follow:

$$D_{FWD}=\beta \cdot P \quad (1)$$

In which: D_{FWD}: FWD measured deflection (μm)

P : FWD exerted changeable load (kN)

β : proportion coefficient, according to the measured values

When using, first calculating conversion coefficient β, according to measured D_{FWDs} and P_s, then calculating the deflection D_{FWD} under P=50kN, so we obtain the pavement deflection (basins) in the unified characteristic load P=50kN.

4 THE DISCUSS ABOUT THE TEMPERATURE CORRECTION OF DEFLECTION (BASINS)

Asphalt pavement appears viscous-elastic character in high temperature, appears elastic character in low temperature, so the influence caused by temperature is more complicated than the relationship between loads and deflection basins. Denis, working in transportation bureau of Quebec in Canada, believes that the best way to do temperature correction is using modulus and the effect is clear, the influence scope caused by temperature is four times the depth of asphalt layer. Figure2a is 4×（50+150）=800mm, Figure2b is the result that Denis used $E_1=10^{(4.05-0.016T)}$ to correct, the correction is effective. The suitable scope of this formula is not clear; it is hard to determine whether it is suitable for China. Meanwhile, for the bad-distributed structure, the parameters of pavement have random characters, it appears that the shapes of deflection basins are much different, so it is feasible to correct deflection (basins) by modulus, but the using of it has limitation.

Figure2a: the influence scope by temperature of deflection basins

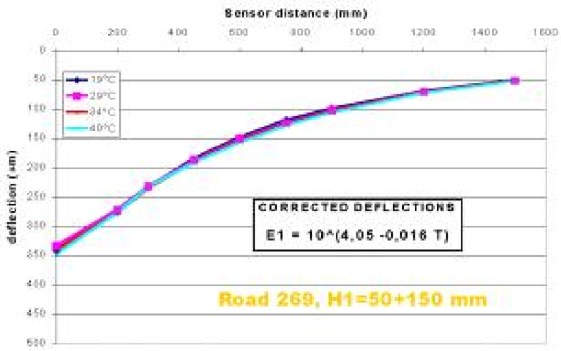

Figure2b: temperature correction of deflection basins

It is necessary to do temperature correction, but it is also complex. To practical angle, this paper emphatically discusses the deflection correction in the center of load, to provide basis for general investigation of pavement deflections or construction checking.

There are two ways to do temperature correction for deflections of FWD. One is establishing correction formula by the measured data of FWD, it is the experience relationship among deflections or deflections increment in the same dashed load and temperature or temperature difference and the depth of asphalt layers (temperature correction only must chooses this way). The other is that converting the measured deflections D_{FWD} of FWD to deflections D_{BB} of Benkelman in characteristic load first, and then converting to deflections under characteristic temperature (20°C) by current temperature correction equation.

Practice illustrates that the temperature correction equation of deflection (basins) by the first way needs amounts of measured data. There are not enough data accumulated. Before establishing temperature correction equation of deflection (basins), we should take the second correction way, which is adopting the deflections temperature correction way of Benkelman Beam recommended in JTJ059-95.

$$L_{20℃} = L_T \times K \qquad (2)$$

$$K = e^{\left(\frac{1}{T} - \frac{1}{20}\right)h} \qquad (T \geq 20℃)$$

$$K = e^{0.002\,h(20-T)} \qquad (T \leq 20℃)$$

In which: $L_{20℃}$: deflections at 20℃(0.01mm)

L_T : deflections when the average temperature in asphalt layer is T℃ (0.01mm)

K : coefficient of temperature correction

h : depth of asphalt layer (cm)

T : the average temperature of asphalt pavement when measuring, adopting manual measurement

5 THE CONVERSION RELATIONSHIP BETWEEN DEFLECTIONS D_{FWD} OF FWD AND D_{BB} OF BENKELMAN BEAM

Although the natures of load application by the two ways (BB and FWD) are different, by theory analysis, it is testified that not only the mobile load but also the quiescent load can be analyzed by the common elastic layered theory, the errors being in the allowable scope (Garg and H.Marsey, 2002, Ren, 2000). That is to say that although the natures of the two methods are different, there exits certain relationship between them, which can be established by relative analysis. JTJ059-95 prescribes that the relative coefficient must reach 0.90 or exceed it (Standard of Ministry of Communition of PRC, 1995).

The relationship between D_{FWD} and D_{BB} established by contract test is almost D_{BB}=a+b•D_{FWD}. But because there are great differences among the base and pavement conditions of different areas, and there are obvious area characters among pavement structures, it is not actual to establish unified correction equation in the whole country, and the regressive coefficients must be great different among different area.

Figure3 is the gathered table of the measured data from typical sections of asphalt pavements with line-flyash base in Jilin province, which includes the points-figure in which the dubious data are deleted by Chauvenet criterion and the points-figure considering load correction. Table3 gives the analysis result of measured data by linear regressing, which indicates that the linear relationship between D_{FWD} and D_{BB} is notable. This illustrates that for the typical pavements with bounded base in Jilin province, pavement structure influences the linear conversion relationship a little established between D_{FWD} and D_{BB}, and it is feasible to adopt the unified conversion equation in table3 for this type of pavement structure.

Table3: The analysis result by linear regression (equation：D_{BB}=a+b·D_{FWD})

Number	Regression coefficient a	Regression coefficient b	Related coefficient $R/R_{\alpha=0.01}$	Significance test $F/F_{\alpha=0.01}$	Annotation
294	8.0446	0.0915	0.9661/0.181	4082/6.76	Deleting dubious data
294	8.6842	0.0884	0.9688/0.181	4457/6.76	After load correction

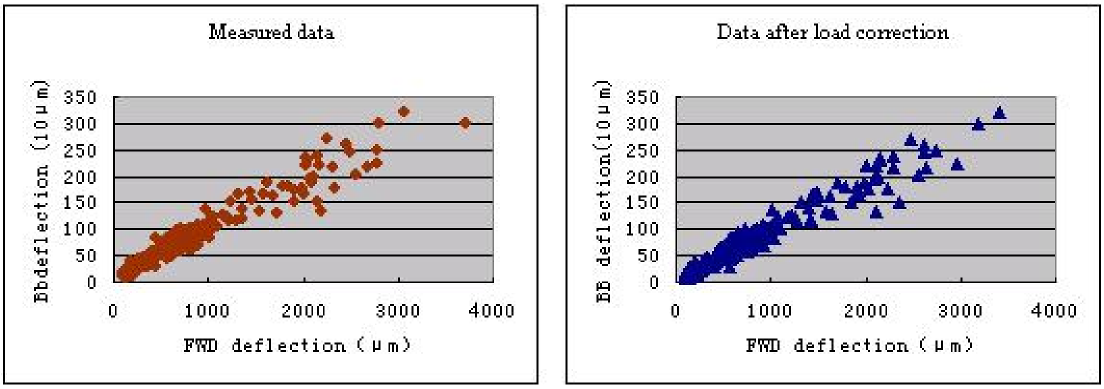

Figure3: Gathered figures of data

6 CONCLUTION

This paper discusses the necessity of doing load and temperature correction when measuring deflections by FWD, by analyzing the achievement of FWD application inside and outside the country, combining the test data of Jilin province. For the current application condition of FWD in our country, this paper suggests that China should strengthen the introduction of the second application of FWD, raise the application ratio of it, and expand the application scope. Meanwhile, China should establish calibration center of FWD which is suitable for our own country and establish design and evaluation standards in the base of the load pattern of FWD to raise the authority of the measured data with FWD.

REFERENCES

Feng, Tang and Li, 1996. *Nondestructive Evaluation with FWD on Structural Bearing Capacity of Asphalt Pavements*. Journal of Tongji University.

Garg and H.Marsey. *Comparison Between Falling Weight Deflectometer And Static Deflection Measurement On Flexible Pavement At The National Airport Pavement Test Facility*.The 2002 Feaderal Aviation Administration Airport Technology Transfer Conference.

Ren, 2000. *The Study of Asphalt Pavement Structure Calculation and FWD Application Technique*. Doctoral Dissertation of Harbin University of Civil Engineering and Architecture.

Standard of Ministry of Communition of PRC.1995. *Field Test Methods of Subgrade and Pavement for Highway Engineering*. JTJ059-95

Song, He and Feng, 2000. *Testing Study on Relations of Pavement Deflection*. Journal of Zhengzhou University of Technology.

Tang, Deng and Li, 1990. Comparison Reasearch between FWD and BB. China Journal of Highway and Transport.

Tholen. *Comparison of Falling Weight Deflectometer With Other Deflection Testing Device*. TRR1007.

Zeng, Zhang and Cheng, 2001. *Analysis of Dependence Relation of FWD and Beckman Beam Used in Pavement Detection*. Highway.