INPUT GUIDE FOR COMPUTER PROGRAM ILSL2

(REVISED VERSION: MARCH 14, 1994)

Program ILSL2, an extension of the widely-used finite element program ILLISLAB, can be used to calculate deflections and stresses in jointed slab-on-grade pavements, with or without load transfer systems. The program can also accommodate a stabilized base or an overlay, by assuming either no bond (ICOMP = 0) or perfect bond (ICOMP = 1) between the two constructed layers, which are both modeled as plates. Note that setting ICOMP = 0 dictates that the two unbonded plates retain the same deflection profile. An important new feature of ILSL2 is its ability to analyze compressibility and separation of unbonded layers (ICOMP = 2). The new option requires the assignment of an interlayer stiffness parameter, kI. The latter might be selected by the user or be determined using the Modified Totsky Equation. Only one slab panel is currently allowed when using this option.

Additional distinguishing features of ILSL2 include the capability to accommodate a variety of subgrade support characterization options. In addition to the more conventional WINKLER (IST = 6) and SPRINGS (IST = 7) idealizations, the program incorporates the elastic solid (BOUSSINESQ, IST = 8), two-parameter (VLASOV, IST = 9), three-parameter (KERR, IST = 10), and Zhemochkin-SinitsynShtaerman (ZSS, IST = 11) formulations. For subgrade options with IST greater than or equal to 8, only one slab panel is allowed. Furthermore, this slab must have a constant thickness and elastic modulus and must consist of only one layer. The symmetry capability is now operable with all options. The LINPACK routines, used with the BOUSSINESQ subgrade model, were developed at Argonne National Laboratories, and should be acknowledged as such in any resulting publications. The RESILIENT, VLASOV, KERR and ZSS subgrade options are intended primarily for research purposes. The relevant literature must be consulted before using these models.

Another distinguishing feature of ILSL2 lies in its treatment of temperature curling effects. The program allows the computation of deflections and stresses due to a temperature gradient through the thickness of the slab (ITEMP = 1). Linear (IPRZ = 0 or 1) or nonlinear (IPRZ = 2 or 3) temperature distributions through the thickness of the slab can be accommodated. Wheel loads and gaps underneath the slab can also be accommodated when this option is used. Cards No. 3, 13, 16, 30, 31, 32, 35, 36 and 37 contain the pertinent inputs if deflections and stresses due to a temperature gradient and gaps are to be computed. In considering curling effects, single slabs can be analyzed using the SPRINGS, WINKLER or BOUSSINESQ subgrades, whereas multiple slab systems can be analyzed using the SPRINGS or WINKLER subgrade models only. In the latter case, dowel bars and/or aggregate interlock can be used as load transfer mechanisms. The self-weight of the slab should be taken into account in curling analysis (see Cards No. 13 and No. 16).

In all other respects, ILSL2 works in a manner identical to the latest version of ILLI-SLAB (version date: 3/15/89). In general, the pavement system can consist of any number of slabs. The program is currently dimensioned to accept up to 10 slabs along each of the x-and y-axes. Elements and nodes are numbered consecutively from bottom to top along the y-axis, and from left to right along the x-axis. Joints are treated as rectangular elements having zero width. The wheel loads may be applied to any of the slabs, and stresses and deflections at all nodes in the slab, stresses in the stabilized base or overlay, vertical stresses in the subgrade, and loads transferred by dowel bars or aggregate interlock are computed.

The subgrade modulus may vary at the nodes (see Cards No. 19 and 20). When dowels are specified, loads may be transferred by shear, torsion or moment, or any combination of these. The default load transfer mechanism is by shear and moment. Dowel spacing need not be uniform, and dowel bars may be specified at any node along an edge. For this purpose, Cards No. 9, No. 10, No. 22, No. 23, No. 26 and No. 27 need to be provided.

ILSL2 can be used with any consistent system of units. The notation for the various fundamental quantities used in this write-up is:

Length	[L]
Force	[F]
Temperature	[θ]

For example, using the American system of units, the unit of length is the inch (in.), the unit of force is the pound (lb), and the unit of temperature is the degree Fahrenheit (°F).

The present version of ILSL2 (March 14, 1994) accepts fixed form input only, as described below. It is usually implemented on a personal computer (386-DX or higher), and should be compiled using a 32-bit FORTRAN compiler. It uses up to 900,000 memory spaces and double precision arithmetic, requiring 16 Mb of RAM. To change the memory core (so that the program may be accommodated on any given machine), the user should go into the MAIN PROGRAM and substitute the two occurrences of the number 900000 by the appropriate array length available.

Users of ILSL2 are requested to acknowledge its use in any resulting publications using the following reference:

Khazanovich, L. and Ioannides, A.M. (1993), "Finite Element Analysis of Slabs-On-Grade Using Improved Subgrade Soil Models," Proceedings, ASCE Specialty Conference 'Airport Pavement Innovations--Theory to Practice,' Waterways Experiment Station, Vicksburg, MS, September 810, pp. 16-30.

Additional references to earlier versions of ILLI-SLAB would also be appreciated. These may include:

Tabatabaie, A.M. and Barenberg, E.J. (1980), "Structural Analysis of Concrete Pavement Systems," Transportation Engineering Journal, ASCE, Vol. 106, No. TE5, Sept., pp. 493-506. [For the original version (1977), and later]

Ioannides, A.M., Thompson, M.R., and Barenberg, E.J. (1985), "Finite Element Analysis of Slabs-On-Grade using a Variety of Support Models," Proceedings, Third International Conference on Concrete Pavement Design and Rehabilitation, Purdue University, W. Lafayette, IN, pp. 309-324. [For version 6/04/83, and later]

Ioannides, A.M. and Korovesis, G.T. (1992), "Analysis and Design of Doweled Slab-On-Grade Pavement Systems," Journal of Transportation Engineering, ASCE, Vol. 118, No. 6, Nov./Dec., pp. 745-768. [For version 3/15/89, and later]

CARDS FOR FIXED-FORM INPUT FOR ILSL2

Card No. 1.

IFORM
I1

IFORM: A numeric flag indicating type of input data type used;

= 0, for free-form input;

= 1, for fixed-form input.

Card No. 2.

TITLE
20A4

TITLE: An 80-column label of alphanumeric characters used to identify the problem. This label will appear on the header part of the output.

Card No. 3.

NFOR	ISYM	ITEMP	IPRZ	TREF
I5	I5	I5	I5	F10.3

NFOR: Number of loaded areas.

ISYM: Numeric flag indicating whether symmetry lines are used;

= 0, if no symmetry lines are used;

= 1, if x-axis is a line of symmetry;

= 2, if y-axis is a line of symmetry;

= 3, if x-axis and y-axis are lines of symmetry;

ITEMP: Numeric flag indicating whether temperature differentials or gaps exist;

= 0, if no temperature differentials nor gaps exist;

= 1, if otherwise.

IPRZ: Numeric flag indicating the model to be used in curling analysis;

= 0, for the Przemieniecki linear distribution model;

= 1, for the WESLIQID linear distribution model (for single-slab, single-layer systems only);

= 2, for quadratic nonlinear temperature distribution in each of up to two layers;

= 3, for general nonlinear temperature distribution in each of up to two layers.

TREF: Reference temperature. May be left blank if IPRZ<2 or ICOMP 1.

Card No. 4.

NNODX(I); I=1,MAXSLXY
10I5

NNODX(I): Number of nodes in slab(s), along the x-axis (MAXSLXY is set to 10; to change, alter the size of arrays NNODX and NNODY).

Card No. 5.

NNODY(I); I=1,MAXSLXY
10I5

NNODY(I): Number of nodes in slab(s), along the y-axis (MAXSLXY is set to 10; to change, alter the size of arrays NNODX and NNODY).

Card No. 6.

NLAYER	ICOMP	CK	E0	PR0
I5	I5	F10.3	F10.3	F10.3

NLAYER: Number of layers above subgrade: 1 or 2.

ICOMP: Composite action factor;

= 0, for unbonded layers;

= 1, for fully bonded layers;

= 2, for unbonded layers with possible separation and compressibility (Totsky model).

CK:

For IST = 6 or 7, Modulus of subgrade reaction, [FL-3], if uniform; otherwise set CK = 0.0, if not uniform (see Card No. 19);

For IST = 10 or 11, Spring stiffness for the upper spring layer [FL-3];

For IST = 8, set CK = -1.0;

E0:

For IST = 8 or 11, Elastic Modulus of subgrade [FL-2];

For IST = 9 or 10, the shear parameter, GM [FL-1];

For ICOMP = 2, Interlayer Spring Stiffness, kI [FL-3];

Otherwise, leave blank.

PR0:

For IST = 8 or 11, Poisson's Ratio of subgrade [-];

For IST = 10, Spring stiffness for the lower spring layer [FL-

3];

Otherwise, leave blank.

Note : If ICOMP = 2 and E0 is not positive, then the Modified Totsky Equation is used for the calculation of kI.

Card No. 7.

IST	ITMAX	TOL1	TOL2	IOT
I5	I5	F5.3	F5.3	I5

IST: A numeric flag for subgrade type:

= 0, if subgrade type varies (See Card No. 33);

= 1, for VERY SOFT subgrade;

= 2, for SOFT subgrade;

= 3, for MEDIUM subgrade;

= 4, for STIFF subgrade;

= 5, for OTHER subgrade (see Card No. 34);

= 6, for WINKLER energy consistent, uniform subgrade;

= 7, for SPRINGS subgrade;

= 8, for BOUSSINESQ subgrade;

= 9, for VLASOV subgrade;

= 10, for KERR subgrade;

= 11, for ZSS subgrade.

Note that options IST = 1, 2, 3 and 4 are only operable using American units (i.e. lbs and in.). For these, recommended values for KR in first iteration are as follows:

VERY SOFT: KR = 300 psi/in.;

SOFT: KR = 425 psi/in.;

MEDIUM: KR = 725 psi/in.;

STIFF: KR = 1000 psi/in.;

OTHER: KR = A5/DY psi/in.

ITMAX: Maximum number of iterations desired.

TOL1: Tolerance for KR (Recommended value = 0.05, i.e. 5%).

TOL2: Tolerance for points exceeding TOL1 (Recommended value = 0.05, i.e. 5%).

IOT: Numeric flag for output type:

= 0, for partial output during intermediate iterations;

= 1, for full output during intermediate iterations.

Note: A new iteration is performed if the ratio of the number of nodes at which the updated KR is more than TOL1 (%) off the previous KR, to the total number of nodes, exceeds TOL2 (%).

Card No. 8.

ICON(I); I=1,6	ISTEP
6I1	I4

ICON(I): A numeric flag indicating which contour plots, if any, are desired;

ICON(1) = 1, if contours of deflection are wanted; = 0, if not;

ICON(2) = 1, if contours of subgrade stress are wanted; = 0, if not.

ICON(3) = 1, if contours of x-stress at bottom of Layer 1 are wanted; = 0, if not.

ICON(4) = 1, if contours of y-stress at bottom of Layer 1 are wanted; = 0, if not.

ICON(5) = 1, if contours of x-stress at bottom of Layer 2 are wanted; = 0, if not.

ICON(6) = 1, if contours of y-stress at bottom of Layer 2 are wanted; = 0, if not.

ISTEP: An integer specifying the density of the Virtual Grid in the contouring routines. The value of 40 produces pleasing contours. For coarser but quicker lower the value. For smoother but longer time raise the value. ISTEP should be less than 200.

NB: ICON(5) and ICON(6) must be set to 0, if NLAYER = 1 (see Card No. 6).

Card No. 9 (Read only if there are more than one slabs along x-axis).

LTDX	IBARXT	IBARXS	IBARXM
4I5			

LTDX: Type of load transfer in x-direction;

= 0, if aggregate interlock;

= 1, if dowel bars;

= 2, if a combination of dowel bars and aggregate interlock.

IBARXT: Numeric flag for torsion on the dowel bars in x-direction;

= 0, if torsion is not to be considered (default);

= 1, if torsion is to be considered.

IBARXS: Numeric flag for shear on the dowel bars in x-direction;

= 0, if shear is not to be considered;

= 1, if shear is to be considered (default).

IBARXM: Numeric flag for moment on the dowel bars in x-direction;

= 0, if moment is not to be considered;

= 1, if moment is to be considered (default).

Card No. 10 (Read only if there are more than one slabs along y-axis).

LTDY	IBARYT	IBARYS	IBARYM
4I5			

See Card No. 9 for notations.

Card No. 11 (Use as many as needed).

XC(I); I=1,number of nodes along x-axis
8F10.3

XC(I): x-coordinate of nodes along x-axis (read in ascending order), [L].

Card No. 12 (Use as many as needed).

YC(I); I=1,number of nodes along y-axis
8F10.3

YC(I): y-coordinate of node along y-axis (read in ascending order), [L].

Card No. 13.

CT1	CE1	V(1)	CC1	ALPHA1	DT10	DT11	DT12
F10.3	E10.3	6F10.3					

CT1: Top layer thickness, if uniform, [L];

= 0.0, if not (see Card No. 14).

CE1: Modulus of Elasticity for top layer, if uniform, [FL-2];

= 0.0, if not (see Card No. 15).

V(1): Poisson's ratio of top layer.

CC1: Unit weight of the top layer of the slab, [FL-3].

ALPHA1: Coefficient of thermal expansion for layer 1, [LL-1T-1].

DT10: Difference in Temperature, [θ] between the top and bottom surfaces of layer 1, if IPRZ = 0 or IPRZ = 1; temperature at the top surface, if IPRZ = 2.

DT11: Temperature at the midplane of the top layer if IPRZ = 2 (leave blank otherwise), [θ].

DT12: Temperature at the bottom of the top layer if IPRZ = 2 (leave blank otherwise), [θ].

Card No. 14 (Read only if CT1 = 0.0 in Card No. 13; use as many as needed).

T1(I); I=1,number of nodes
8F10.3

T1(I): Thickness of the top layer at node I, [L].

Card No. 15 (Read only if CE1 = 0.0 in Card No. 13; use as many as needed).

E1(I); I=1,number of nodes
8F10.3

E1(I): Modulus of Elasticity of the top layer at node I, [FL-2].

Card No. 16 (Read only if NLAYER=2 in Card No. 6).

CT2	CE2	V(2)	CC2	ALPHA2	DT20	DT21	DT22
F10.3	E10.3	6F10.3					

CT2: Bottom layer thickness, if uniform, [L];
= 0.0, if not (see Card No. 17).

CE2: Modulus of Elasticity for bottom layer, if uniform, [FL-2];
= 0.0, if not (see Card No. 18).

V(2): Poisson's ratio of bottom layer.

CC2: Unit weight of the top layer of the slab, [FL-3].

ALPHA2: Coefficient of thermal expansion for layer 2, [LL-1T-1].

DT20: Difference in Temperature, [θ], between the top and bottom surfaces of layer 2, if IPRZ = 0 or IPRZ = 1; temperature at the top surface, if IPRZ = 2.

DT21: Temperature at the midplane of layer 2 if IPRZ = 2 (leave blank otherwise), [θ]

DT22: Temperature at the bottom of layer 2 if IPRZ = 2 (leave blank otherwise), [θ]

Card No. 17 (Read only if CT2 = 0.0 in Card No. 16; use as many as needed).

T2(I); I=1,number of nodes
8F10.3

T2(I): Thickness of the bottom layer at node I, [L].

Card No. 18 (Read only if CE2 = 0.0 in Card No. 16; use as many as needed).

E2(I), I=1,number of nodes

8F10.3

E2(I): Modulus of Elasticity of the bottom layer at node I, [FL-2].

Card No. 19 (Read only if CK = 0.0 in Card No. 6).

CK1	NNU
F10.3	I5

CK1: Modulus of subgrade reaction for the majority of nodes, [FL-3].

NNU: Number of nodes with different modulus of subgrade reaction.

Card No. 20 (Read only if NNU > 0 in Card No. 19).

I, SUB(I), I=1	NNU
I3	F10.3

(I): Node number of node with different subgrade modulus than CK1.

SUB(I): Modulus of subgrade reaction for node I, [FL-3].

Card No. 21 (Read only if LTDX = 1 or 2 in Card No. 9).

DIN	DOUT	DE	DS	DJW	DPR	DCI
F10.3	F10.3	E10.3	F10.3	F10.3	F10.3	E10.3

DIN: Inside diameter of dowel bars, [L];

= 0.0 for solid round bars.

DOUT: Outside diameter of dowel bars, [L].

DE: Modulus of elasticity of dowel bars, [FL-2].

DS: Spacing of dowel bars, [L]. (Set DS=0.0, if spacing is non-uniform; see Card No. 22).

DJW: Joint width, [L].

DPR: Poisson's Ratio of dowel bars.

DCI: Dowel-Concrete Interaction, [FL-1].

DCI for a round steel dowel bar may be determined from either Friberg's dowel analysis, or from a relation developed on the basis of three-dimensional finite element results, as follows:

(a) Friberg's Analysis:

$$\mathrm{DCI} = \frac{4\beta^3 E_S I_D}{2 + \beta D_{JW}}$$

DCI={4*BETA3*ES*I/(2+BETA*DJW)}**

where:

$$\beta = \left(\frac{K_D}{4E_s I_D}\right)^{0.25} \qquad [L-1];$$

BETA=[KD/(4*ES*I)]0.25, [L-1]**;

E_S: Steel modulus of elasticity, [FL-2];

I_D: Dowel moment of inertia, [L4];

$$I_D = \frac{\left(\frac{D_D}{2}\right)^4 \pi}{4}$$

={(D/2)4}*3.14159/4;**

K_D: Modulus of dowel support, [FL-3];

D_D: Dowel diameter, [L]; and

D_{JW}: Joint width, [L];

(b) Three-dimensional Analysis (valid for American units only):

$$DCI = \frac{E_C^{0.75}}{(0.057 - 0.10 D_D)(0.810 + 0.013 h)(1 + 0.414 D_{JW})}$$

DCI={E0.75}/{(0.057-0.010*D)*(0.810+0.013*h)*(1+0.414*DJW)}**

where:

E_C: Concrete modulus of elasticity, psi;

D_D: Dowel diameter, in.;

h : Slab thickness, in.; and

D_{JW}: Joint width, in.;

K_D: Modulus of dowel support, psi/in.

Card No. 22 (Read only if DS = 0.0 in Card No. 21).

NDNX
I5

NDNX: Number of nodes at which dowels will be explicitly specified, in x-direction.

Card No. 23 (Read only if DS = 0.0 in Card No. 21).

NDX(I); I=1,NDNX
16I5

NDX(I): Node number of node at which a dowel is explicitly specified, in x-direction.

Card No. 24 (Read only if LTDX = 0 or 2 in Card No. 9).

AGGX
E10.3

AGGX: Aggregate Interlock Factor in x-direction, [FL-2]. (For keyways use a large value, e.g. AGGX=1.0E+08 psi, if American units are used).

Card No. 25 (Read only if LTDY = 1 or 2 in Card No. 10).

DIN	DOUT	DE	DS	DJW	DPR	DCI
F10.3	F10.3	E10.3	F10.3	F10.3	F10.3	E10.3

See Card No. 21 for notations.

Card No. 26 (Read only if DS = 0.0 in Card No. 25).

NDNY
I5

NDNY: Number of nodes at which dowels will be explicitly specified, in y-direction.

Card No. 27 (Read only if DS = 0.0 in Card No. 25).

NDY(I); I=1,NDNY
16I5

NDY(I): Node number of node at which a dowel is explicitly specified.

Card No. 28 (Read only if LTDY = 0 or 2 in Card No. 10).

AGGY

E10.3

AGGY: Aggregate Interlock Factor in y-direction, [FL-2]. (For keyways use a large value, e.g. AGGY = 1.0E+08 psi, if American units are used).

Card No. 29 (Read NFOR times; see Card No. 3).

PRS	XX1	XX2	YY1	YY2
F10.3	F10.3	F10.3	F10.3	F10.3

PRS: Tire pressure, [FL-2].

XX1, XX2: Lower and upper limits of the loaded area in x-direction, in global coordinate system, [L].

YY1, YY2: Lower and upper limits of the loaded area in y-direction, in global coordinate system, [L].

Card No. 30 (Read only if IPRZ = 3).

NTEM1	NTEM2
I5	I5

NTEM1: Number of input points for a temperature distribution in Layer 1.

NTEM2: Number of input points for a temperature distribution in Layer 2 (leave blank if NLAYER = 1)

Card No. 31 (Read NTEM1 times if IPRZ = 3).

HTEM(I)	TEML(I)

F10.3	F10.3

HTEM(I): Depth at the location I, [L].

TEML(I): Temperature at the location I, [θ].

Card No. 32 (Read NTEM2 times if IPRZ = 3 and NLAYER = 2).

HTEM(I)	TEML (I)
F10.3	F10.3

HTEM(I): Depth at the location I, [L].

TEML(I): Temperature at the location I, [θ].

Card No. 33 (Read only if IST = 0 in Card No. 7; use as many as needed).

NST(I); I=1,number of nodes
8I5

NST(I): Subgrade Type (IST) under node I. See Card No. 7 for definition of various subgrade types. IST may take values between 1 and 7, here.

Card No. 34 (Read only if IST=5 in Card No. 7).

A1	A2	A3	A4	A5	DY
6F10.5					

A1, A2, A3, A4, A5, DY: Parameters for the regression equation defining KR as function of w. General form of the equation:

$$KR = \frac{A1\left\{1 - \exp\left[- A2\left(\frac{w}{DY} - A3\right)\right]\right\} + A4\left(\frac{w}{DY} - A3\right) + 2}{w}$$

$$KR = \frac{A5}{DY}, \text{ if } \frac{w}{DY} < A3$$

KR= {A1[1-exp{-A2(w/DY-A3)}]+A4(w/DY-A3)+2}/w KR= A5/DY, if w/DY<A3.

where:

w: deflection, [L];

KR: resilient subgrade modulus, [FL-3].

Card No. 35 (Read only if ITEMP = 1; see Card No. 3).

NOTC	IGAP	ICYCLE
I5	I5	I5

NOTC: Number of nodes at which reactive pressure is initially set to zero.

IGAP: Number of nodes where gaps exist underneath the slab.

ICYCLE: Maximum number of iterations requested.

Card No. 36 (Read only if NOTC > 0 in Card No. 32; use as many as needed).

NODC(I); I=1,NOTC
16I5

NODC(I): Node number of node with zero initial reactive pressure.

Card No. 37 (Read only if IGAP > 0 in Card No. 32; use as many as needed).

NG(I); I=1,IGAP	GAP(NG(I); I=1,IGAP
5I5	**5F10.3**

NG(I): Node number of node with a gap.

GAP(NG(I)): Amount of gap at node NG(I), [L].

Card No. 38 (Read only if contours are to be plotted).

JCON(I); I=1,6	RATIO
6I1	F10.7

JCON(I): A numeric flag indicating over which slabs the contours requested in Card No. 8, are to be plotted (Contours can only be plotted over the first 6 slabs);

= 1, if contours over Slab I are to be plotted;

= 0, if not.

RATIO: A factor by which the y-scale is multiplied;

= 1.0 specifies x- and y-scales are equal.