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1. 緒言

著者らは先に、一対辺が任意向隅の中間支柱にて支持され、他対辺が単純支持される矩形板に任意垂直荷重が作用する場合の解法を發表⁽¹⁾⁽²⁾したが、つづいて接線方向の二辺が中間支柱にて剛結支持され、法線方向の二辺が単純支持される等方性等断面扇形平板の解法を提示し、かつ構造物の解析ならびに設計に資せんとするものである。

2. 解法

(1) 板の弾性曲面 一般に板と柱とが直交して剛結される場合には、板から柱に垂直反力、法線および接線方向の水平反力、曲げモーメントおよび捻りモーメントが与えられるが、板面に対して垂直荷重が働く場合には、板面内の捻りモーメントおよび水平反力はそれだけ微小であるからこれらを無視することとする。

図-1のごとく極座標 (r, θ) とこれらに直交する W 軸を導入する。板 $ABCD$ は法線方向の辺 AB 、 DC で単純支持され、また、接線方向の辺 AD は f 個 $(i=1, 2, \dots, f)$ の中間支柱で、辺 BC は s 個 $(j=1, 2, \dots, s)$ の中間支柱で剛結支持されるものとする。板に垂直荷重 $p(r, \theta)$ が作用し、かつ、辺 AB 、 DC の境界条件を満足するとき板の弾性曲面 w は次式であらわされる(文献(3)参照)。

$$w = \sum_{n=1}^{\infty} \{ A_n r^{\alpha_n} + B_n r^{-\alpha_n} + C_n r^{2+\alpha_n} + D_n r^{2-\alpha_n} + F_n(r) \} \sin \alpha_n \theta \quad (1)$$

$\alpha > 1$: A_n, B_n, C_n, D_n : 積分定数, $\alpha_n = n\pi/\alpha$,

$F_n(r) = f_n r^4 / D(16 - \alpha^2)(4 - \alpha^2)$, D : 板剛度

$$f_n = \frac{2}{\alpha} \int_0^{\alpha} p(r, \theta) \sin \alpha_n \theta d\theta,$$

積分定数 $A_n \sim D_n$ は、 $r=r_1, r_2$ における辺 AD 、

BC の境界条件を満足することと決定されなければならない。すなわち、辺 AD 、 BC に

おける反力および法線方向の曲げモーメントをそれぞれ正弦フーリエ級数にてあらわせば

上述の境界条件式は次のごとく与えられる。

$$\left. \begin{aligned} r=r_1: & \quad V_r = -D \left\{ \frac{\partial w}{\partial r} + (2-\nu) \left(\frac{1}{r} \frac{\partial w}{\partial \theta} \right) - \frac{1}{r^2} \frac{\partial w}{\partial r} + \frac{1}{r^2} \frac{\partial^2 w}{\partial \theta^2} - \frac{2}{r^3} \frac{\partial w}{\partial \theta} \right\} = \sum_{n=1}^{\infty} V_{An} \sin \alpha_n \theta, \quad M_r = -D \left\{ \frac{\partial^2 w}{\partial r^2} + \nu \left(\frac{1}{r} \frac{\partial w}{\partial r} + \frac{1}{r^2} \frac{\partial^2 w}{\partial \theta^2} \right) \right\} = \sum_{n=1}^{\infty} M_{An} \sin \alpha_n \theta \\ r=r_2: & \quad V_r = -D \left\{ \frac{\partial w}{\partial r} + (2-\nu) \left(\frac{1}{r} \frac{\partial w}{\partial \theta} \right) - \frac{1}{r^2} \frac{\partial w}{\partial r} + \frac{1}{r^2} \frac{\partial^2 w}{\partial \theta^2} - \frac{2}{r^3} \frac{\partial w}{\partial \theta} \right\} = \sum_{n=1}^{\infty} V_{Bn} \sin \alpha_n \theta, \quad M_r = -D \left\{ \frac{\partial^2 w}{\partial r^2} + \nu \left(\frac{1}{r} \frac{\partial w}{\partial r} + \frac{1}{r^2} \frac{\partial^2 w}{\partial \theta^2} \right) \right\} = \sum_{n=1}^{\infty} M_{Bn} \sin \alpha_n \theta \end{aligned} \right\} \quad (2)$$

ただし $V_{An}, V_{Bn}, M_{An}, M_{Bn}$: 任意定数 ν : 板のポアソン比

式(1)を式(2)に代入のうえ、連立に解けば積分定数 $A_n \sim D_n$ は次式のごとく求められる。

$$\left. \begin{aligned} A_n &= [P_{AD} \frac{M_{An}}{D} + Q_{AD} \frac{M_{Bn}}{D} + R_{AD} \frac{V_{An}}{D} + S_{AD} \frac{V_{Bn}}{D} + Q_{AD}] / E_0, & B_n &= [P_{BD} \frac{M_{An}}{D} + Q_{BD} \frac{M_{Bn}}{D} + R_{BD} \frac{V_{An}}{D} + S_{BD} \frac{V_{Bn}}{D} + Q_{BD}] / E_0 \\ C_n &= [P_{CD} \frac{M_{An}}{D} + Q_{CD} \frac{M_{Bn}}{D} + R_{CD} \frac{V_{An}}{D} + S_{CD} \frac{V_{Bn}}{D} + Q_{CD}] / E_0, & D_n &= [P_{DD} \frac{M_{An}}{D} + Q_{DD} \frac{M_{Bn}}{D} + R_{DD} \frac{V_{An}}{D} + S_{DD} \frac{V_{Bn}}{D} + Q_{DD}] / E_0 \end{aligned} \right\} \quad (3)$$

$\alpha > 1$: $Q_{AD} \sim Q_{DD} = K \alpha D F_n^M(r_1) + L \alpha D F_n^M(r_2) + M \alpha D F_n^M(r_1) + N \alpha D F_n^M(r_2)$, $E_0 = E \alpha b E \alpha$, $E_{ab} = 4 \alpha b^2 (\alpha - 1) (\alpha + 1) (1 - \nu)^2 (A_0 A_1 \alpha \alpha + 4 A_2 A_3 \alpha \alpha + 4 A_4 A_5 \alpha \alpha + 4 A_6 A_7 \alpha \alpha + 4 A_8 A_9 \alpha \alpha + 4 A_{10} A_{11} \alpha \alpha + 4 A_{12} A_{13} \alpha \alpha + 4 A_{14} A_{15} \alpha \alpha + 4 A_{16} A_{17} \alpha \alpha + 4 A_{18} A_{19} \alpha \alpha + 4 A_{20} A_{21} \alpha \alpha + 4 A_{22} A_{23} \alpha \alpha + 4 A_{24} A_{25} \alpha \alpha + 4 A_{26} A_{27} \alpha \alpha + 4 A_{28} A_{29} \alpha \alpha + 4 A_{30} A_{31} \alpha \alpha + 4 A_{32} A_{33} \alpha \alpha + 4 A_{34} A_{35} \alpha \alpha + 4 A_{36} A_{37} \alpha \alpha + 4 A_{38} A_{39} \alpha \alpha + 4 A_{40} A_{41} \alpha \alpha + 4 A_{42} A_{43} \alpha \alpha + 4 A_{44} A_{45} \alpha \alpha + 4 A_{46} A_{47} \alpha \alpha + 4 A_{48} A_{49} \alpha \alpha + 4 A_{50} 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A_{699} \alpha \alpha + 4 A_{700} A_{701} \alpha \alpha + 4 A_{702} A_{703} \alpha \alpha + 4 A_{704} A_{705} \alpha \alpha + 4 A_{706} A_{707} \alpha \alpha + 4 A_{708} A_{709} \alpha \alpha + 4 A_{710} A_{711} \alpha \alpha + 4 A_{712} A_{713} \alpha \alpha + 4 A_{714} A_{715} \alpha \alpha + 4 A_{716} A_{717} \alpha \alpha + 4 A_{718} A_{719} \alpha \alpha + 4 A_{720} A_{721} \alpha \alpha + 4 A_{722} A_{723} \alpha \alpha + 4 A_{724} A_{725} \alpha \alpha + 4 A_{726} A_{727} \alpha \alpha + 4 A_{728} A_{729} \alpha \alpha + 4 A_{730} A_{731} \alpha \alpha + 4 A_{732} A_{733} \alpha \alpha + 4 A_{734} A_{735} \alpha \alpha + 4 A_{736} A_{737} \alpha \alpha + 4 A_{738} A_{739} \alpha \alpha + 4 A_{740} A_{741} \alpha \alpha + 4 A_{742} A_{743} \alpha \alpha + 4 A_{744} A_{745} \alpha \alpha + 4 A_{746} A_{747} \alpha \alpha + 4 A_{748} A_{749} \alpha \alpha + 4 A_{750} A_{751} \alpha \alpha + 4 A_{752} A_{753} \alpha \alpha + 4 A_{754} A_{755} \alpha \alpha + 4 A_{756} A_{757} \alpha \alpha + 4 A_{758} A_{759} \alpha \alpha + 4 A_{760} A_{761} \alpha \alpha + 4 A_{762} A_{763} \alpha \alpha + 4 A_{764} A_{765} \alpha \alpha + 4 A_{766} A_{767} \alpha \alpha + 4 A_{768} A_{769} \alpha \alpha + 4 A_{770} A_{771} \alpha \alpha + 4 A_{772} A_{773} \alpha \alpha + 4 A_{774} A_{775} \alpha \alpha + 4 A_{776} A_{777} \alpha \alpha + 4 A_{778} A_{779} \alpha \alpha + 4 A_{780} A_{781} \alpha \alpha + 4 A_{782} A_{783} \alpha \alpha + 4 A_{784} A_{785} \alpha \alpha + 4 A_{786} A_{787} \alpha \alpha + 4 A_{788} A_{789} \alpha \alpha + 4 A_{790} A_{791} \alpha \alpha + 4 A_{792} A_{793} \alpha \alpha + 4 A_{794} A_{795} \alpha \alpha + 4 A_{796} A_{797} \alpha \alpha + 4 A_{798} A_{799} \alpha \alpha + 4 A_{800} A_{801} \alpha \alpha + 4 A_{802} A_{803} \alpha \alpha + 4 A_{804} A_{805} \alpha \alpha + 4 A_{806} A_{807} \alpha \alpha + 4 A_{808} A_{809} \alpha \alpha + 4 A_{810} A_{811} \alpha \alpha + 4 A_{812} A_{813} \alpha \alpha + 4 A_{814} A_{815} \alpha \alpha + 4 A_{816} A_{817} \alpha \alpha + 4 A_{818} A_{819} \alpha \alpha + 4 A_{820} A_{821} \alpha \alpha + 4 A_{822} A_{823} \alpha \alpha + 4 A_{824} A_{825} \alpha \alpha + 4 A_{826} A_{827} \alpha \alpha + 4 A_{828} A_{829} \alpha \alpha + 4 A_{830} A_{831} \alpha \alpha + 4 A_{832} A_{833} \alpha \alpha + 4 A_{834} A_{835} \alpha \alpha + 4 A_{836} A_{837} \alpha \alpha + 4 A_{838} A_{839} \alpha \alpha + 4 A_{840} A_{841} \alpha \alpha + 4 A_{842} A_{843} \alpha \alpha + 4 A_{844} A_{845} \alpha \alpha + 4 A_{846} A_{847} \alpha \alpha + 4 A_{848} A_{849} \alpha \alpha + 4 A_{850} A_{851} \alpha \alpha + 4 A_{852} A_{853} \alpha \alpha + 4 A_{854} A_{855} \alpha \alpha + 4 A_{856} A_{857} \alpha \alpha + 4 A_{858} A_{859} \alpha \alpha + 4 A_{860} A_{861} \alpha \alpha + 4 A_{862} A_{863} \alpha \alpha + 4 A_{864} A_{865} \alpha \alpha + 4 A_{866} A_{867} \alpha \alpha + 4 A_{868} A_{869} \alpha \alpha + 4 A_{870} A_{871} \alpha \alpha + 4 A_{872} A_{873} \alpha \alpha + 4 A_{874} A_{875} \alpha \alpha + 4 A_{876} A_{877} \alpha \alpha + 4 A_{878} A_{879} \alpha \alpha + 4 A_{880} A_{881} \alpha \alpha + 4 A_{882} A_{883} \alpha \alpha + 4 A_{884} A_{885} \alpha \alpha + 4 A_{886} A_{887} \alpha \alpha + 4 A_{888} A_{889} \alpha \alpha + 4 A_{890} A_{891} \alpha \alpha + 4 A_{892} A_{893} \alpha \alpha + 4 A_{894} A_{895} \alpha \alpha + 4 A_{896} A_{897} \alpha \alpha + 4 A_{898} A_{899} \alpha \alpha + 4 A_{900} A_{901} \alpha \alpha + 4 A_{902} A_{903} \alpha \alpha + 4 A_{904} A_{905} \alpha \alpha + 4 A_{906} A_{907} \alpha \alpha + 4 A_{908} A_{909} \alpha \alpha + 4 A_{910} A_{911} \alpha \alpha + 4 A_{912} A_{913} \alpha \alpha + 4 A_{914} A_{915} \alpha \alpha + 4 A_{916} A_{917} \alpha \alpha + 4 A_{918} A_{919} \alpha \alpha + 4 A_{920} A_{921} \alpha \alpha + 4 A_{922} A_{923} \alpha \alpha + 4 A_{924} A_{925} \alpha \alpha + 4 A_{926} A_{927} \alpha \alpha + 4 A_{928} A_{929} \alpha \alpha + 4 A_{930} A_{931} \alpha \alpha + 4 A_{932} A_{933} \alpha \alpha + 4 A_{934} A_{935} \alpha \alpha + 4 A_{936} A_{937} \alpha \alpha + 4 A_{938} A_{939} \alpha \alpha + 4 A_{940} A_{941} \alpha \alpha + 4 A_{942} A_{943} \alpha \alpha + 4 A_{944} A_{945} \alpha \alpha + 4 A_{946} A_{947} \alpha \alpha + 4 A_{948} A_{949} \alpha \alpha + 4 A_{950} A_{951} \alpha \alpha + 4 A_{952} A_{953} \alpha \alpha + 4 A_{954} A_{955} \alpha \alpha + 4 A_{956} A_{957} \alpha \alpha + 4 A_{958} A_{959} \alpha \alpha + 4 A_{960} A_{961} \alpha \alpha + 4 A_{962} A_{963} \alpha \alpha + 4 A_{964} A_{965} \alpha \alpha + 4 A_{966} A_{967} \alpha \alpha + 4 A_{968} A_{969} \alpha \alpha + 4 A_{970} A_{971} \alpha \alpha + 4 A_{972} A_{973} \alpha \alpha + 4 A_{974} A_{975} \alpha \alpha + 4 A_{976} A_{977} \alpha \alpha + 4 A_{978} A_{979} \alpha \alpha + 4 A_{980} A_{981} \alpha \alpha + 4 A_{982} A_{983} \alpha \alpha + 4 A_{984} A_{985} \alpha \alpha + 4 A_{986} A_{987} \alpha \alpha + 4 A_{988} A_{989} \alpha \alpha + 4 A_{990} A_{991} \alpha \alpha + 4 A_{992} A_{993} \alpha \alpha + 4 A_{994} A_{995} \alpha \alpha + 4 A_{996} A_{997} \alpha \alpha + 4 A_{998} A_{999} \alpha \alpha + 4 A_{1000} A_{1001} \alpha \alpha + 4 A_{1002} A_{1003} \alpha \alpha + 4 A_{1004} A_{1005} \alpha \alpha + 4 A_{1006} A_{1007} \alpha \alpha + 4 A_{1008} A_{1009} \alpha \alpha + 4 A_{1010} A_{1011} \alpha \alpha + 4 A_{1012} A_{1013} \alpha \alpha + 4 A_{1014} A_{1015} \alpha \alpha + 4 A_{1016} A_{1017} \alpha \alpha + 4 A_{1018} A_{1019} \alpha \alpha + 4 A_{1020} A_{1021} \alpha \alpha + 4 A_{1022} A_{1023} \alpha \alpha + 4 A_{1024} A_{1025} \alpha \alpha + 4 A_{1026} A_{1027} \alpha \alpha + 4 A_{1028} A_{1029$

$$\begin{aligned}
& +A_3A_7^2t_2t_4t_2^2), Ecd=4(\alpha n+1)A_6(A_8A_9\alpha n-1)t_3t_2-A_4A_5^2\alpha n(\alpha n-1)t_2t_3+A_5^2A_9(\alpha n-1)t_5t_2, \\
& K_1=EcdY_1^2\alpha n\{(2R_1^2t_3-A_6t_4t_2)G_2-2A_7t_3G_1\}, LA=EcdY_1^2\alpha n\{(2R_1^2t_3+A_6t_4t_2)G_1-2A_7A_9G_2\}, MA=EcdY_1^2A_6t_7G_2, NA=-EcdY_1^2A_6A_7G_1, \\
& PA=Y_1^2KA, QA=Y_1^2LA, RA=Y_1^2MA, SA=Y_1^2NA, KB=-EcdY_1^2\alpha n\{(2R_1^2t_3-A_6t_4t_2)H_2-2A_7t_3H_1\}, LB=-EcdY_1^2\alpha n\{(2R_1^2t_3+A_6t_4t_2)H_1-2A_7t_3H_2\}, \\
& MB=-EcdY_1^2A_6t_7H_2, NB=EcdY_1^2A_6t_7H_1, PB=Y_1^2KB, QB=Y_1^2LB, RB=Y_1^2MB, SB=Y_1^2NB, KC=2Eab\{2\alpha n(R_1^2J_1-R_1^2J_2)-(3n-2)A_6J_2\}, \\
& LC=-2Eab\{2\alpha n(R_1^2J_1-R_1^2J_2)-(3n-2)A_6J_1\}, MC=-2EabJ_2A_6, NC=2EabA_6J_1, PC=Y_1^2KC, QC=Y_1^2LC, RC=Y_1^2MC, SC=Y_1^2NC, \\
& KD=2Eab\{2\alpha n(R_1^2I_1-R_1^2I_2)-(3n-2)A_6I_2\}, LD=-2Eab\{2\alpha n(R_1^2I_1-R_1^2I_2)-(3n-2)A_6I_1\}, MP=-2EabA_6I_2, NP=2EabA_6I_1, PD=Y_1^2KP, \\
& QD=Y_1^2LP, RD=Y_1^2MP, SD=Y_1^2NP, \\
& G_1=2\alpha n(\alpha n+1)(1-\nu)R_1\{Y_1^2A_6t_4t_2+R_1^2A_5\alpha n t_3\}, G_2=2\alpha n(\alpha n+1)(1-\nu)R_1\{Y_1^2A_6t_4t_2+R_1^2A_5\alpha n t_3\}, J_1=A_6R_1^2\alpha n(\alpha n-1)t_3+Y_1^2R_1^2A_6(\alpha n-1)t_3, \\
& J_2=A_6R_1^2\alpha n(\alpha n-1)t_3+Y_1^2R_1^2A_6(\alpha n-1)t_3, I_1=-(\alpha n+1)A_4(R_1^2A_5\alpha n t_2+Y_1^2A_6t_3), I_2=-(\alpha n+1)A_4(R_1^2A_5\alpha n t_2+Y_1^2A_6t_3), H_1=2R_1A_7\alpha n(\alpha n-1)(1-\nu) \\
& \times(Y_1^2A_6t_3t_2+A_9\alpha n t_3), H_2=2R_1A_7\alpha n(\alpha n+1)(1-\nu)(Y_1^2A_6t_3t_2+A_9\alpha n t_3), F_1^{(0)}(r)=Y_1^2F_1^{(0)}(r)+Y_1^2F_1^{(0)}(r)-\nu X_2^2F_1(r), \\
& F_1^{(0)}(r)=Y_1^2F_1^{(0)}(r)+Y_1^2(2-\nu)F_1^{(0)}(r)-Y_1^2(2-\nu)(\alpha n+1)F_1^{(0)}(r)+2\alpha n^2(2-\nu)F_1(r), F_1^{(0)}(r)=\frac{\partial}{\partial r}F_1(r), F_1^{(0)}(r)=\frac{\partial^2}{\partial r^2}F_1(r), F_1^{(0)}(r)=\frac{\partial^3}{\partial r^3}F_1(r), \\
& R_1=Y_1^2R_1, R_2=Y_1^2R_2, A_3=Y_1^2R_2, A_4=R_1^2R_2, A_5=Y_1^2R_2^2, A_6=R_1^2-R_2^2, A_7=R_1R_2, A_8=Y_1^2R_1^2-Y_1^2R_2^2, A_9=Y_1^2R_1^2-Y_1^2R_2^2, \\
& t_1=\alpha n(1-\nu)+2(3-\nu), t_2=\alpha n(1-\nu)+2(1+\nu), t_3=\alpha n(1-\nu)-2(1+\nu), t_4=\alpha n(3+\nu)+2(1+\nu), t_5=\alpha n(3+\nu)-2(1+\nu), \\
& t_6=\alpha n(\alpha n+1)(1-\nu)+2(1+\nu), t_7=\alpha n^2(1-\nu)^2-4(1+\nu)^2, t_8=\alpha n^2(1-\nu)^2+4(1+\nu)(3-\nu),
\end{aligned}$$

地方，辺ADの各中間支柱の座標値を $(Y_i, Q_{iA}\alpha)$ ($i=1, 2, \dots, f$) とする。各中間支柱に生ずる垂直力および力モーメントは柱断面の接線方向に沿って等分布するものと仮定し，また，各中間支柱の柱頭に働く接線方向の力モーメントは柱断面区間において接線方向に三角形分布するものとし，これら垂直力および接線方向の力モーメントをそれぞれ変域 $[0, \alpha]$ にて正弦フーリエ級数に展開する。かかるとき，辺ADにおける全力および力モーメントは，各中間支柱におけるかかる等分布力および三角形分布力の総和で与えられるわけ，式(2)の任意変数 V_{An} が次のごとく算定される。

$$V_{An} = \frac{4}{\pi(\alpha\delta\beta R)} \left\{ \frac{5}{6} R_1^A \sin \frac{\pi\pi\delta_0}{2} \sin \pi\pi Q_{1A} + \frac{6}{\alpha\delta\beta R_1} M_{1A}^A \left(\cos \frac{\pi\pi\delta_0}{2} - \frac{2}{\pi\pi\delta_0} \sin \frac{\pi\pi\delta_0}{2} \right) \cos \pi\pi Q_{1A} \right\} \quad (4)$$

ただし， R_1^A : 柱の垂直力， M_{1A}^A : 柱の接線方向の力モーメント， $\delta\alpha$: 柱断面の接線方向の中心に，各中間支柱の柱頭に生ずる接線方向の力モーメントを，柱断面区間において接線方向に一様分布するものとし，これらを変域 $[0, \alpha]$ において正弦フーリエ級数に展開し，その総和を求めれば，板に作用する接線方向の力モーメントが算定され，したがって式(2)の任意変数 M_{An} が次のごとくえられる。

$$M_{An} = \frac{4}{\pi(\alpha\delta\beta R)} \left\{ \frac{5}{6} M_{1A}^A \sin \frac{\pi\pi\delta_0}{2} \sin \pi\pi Q_{1A} \right\}, \quad \text{ただし } M_{1A}^A: \text{柱の接線方向の力モーメント} \quad (5)$$

同様に辺BCの各中間支柱の座標値を $(Y_j, Q_{jB}\alpha)$ ($j=1, 2, \dots, S$) とし，各中間支柱に生ずる垂直力および力モーメントをそれぞれ R_j^B, M_{jB}^B とすれば，式(2)の任意変数 V_{Bn}, M_{Bn} が次のごとく求められる。

$$\left. \begin{aligned} V_{Bn} &= -\frac{4}{\pi(\alpha\delta\beta R)} \left\{ \frac{5}{6} R_j^B \sin \frac{\pi\pi\delta_0}{2} \sin \pi\pi Q_{jB} + \frac{6}{\alpha\delta\beta R_2} M_{jB}^B \left(\cos \frac{\pi\pi\delta_0}{2} - \frac{2}{\pi\pi\delta_0} \sin \frac{\pi\pi\delta_0}{2} \right) \cos \pi\pi Q_{jB} \right\} \\ M_{Bn} &= -\frac{4}{\pi(\alpha\delta\beta R)} \left\{ \frac{5}{6} M_{jB}^B \sin \frac{\pi\pi\delta_0}{2} \sin \pi\pi Q_{jB} \right\} \end{aligned} \right\} \quad (6)$$

式(3)を式(1)に代入し，かつ，式(4)，(5)，(6)を用いて適当のうゑ整理すれば，図-1に示す斜形平板の弾性曲面 w が次式のごとくえられる。

$$\begin{aligned}
w &= \frac{1}{D} \sum_{n=1}^{\infty} \left[\frac{4}{\pi\alpha\delta\beta R} \left(\frac{5}{6} \frac{R_1}{R} \sin \pi\pi Q_{1A} R_1^A - \frac{5}{6} \frac{R_1}{R} \sin \pi\pi Q_{jB} R_j^B \right) \right. \\
&+ \frac{4}{\pi\alpha\delta\beta R} \sin \frac{\pi\pi\delta_0}{2} \left(\frac{5}{6} \frac{M_{1A}^A}{R} \sin \pi\pi Q_{1A} M_{1A}^A - \frac{5}{6} \frac{M_{jB}^B}{R} \sin \pi\pi Q_{jB} M_{jB}^B \right) \\
&+ \frac{24}{\pi(\alpha\delta\beta R)} \left(\cos \frac{\pi\pi\delta_0}{2} - \frac{2}{\pi\pi\delta_0} \sin \frac{\pi\pi\delta_0}{2} \right) \left(\frac{5}{6} \frac{R_1}{R} \cos \pi\pi Q_{1A} M_{1A}^A - \frac{5}{6} \frac{R_1}{R} \cos \pi\pi Q_{jB} M_{jB}^B \right) + \Omega + F_n(r) \Big] \sin \pi\pi Q \quad (7)
\end{aligned}$$

$$\text{たゞし } \Omega = \sum F_1^M(n) + \eta \sum F_1^M(n_2) + \rho \sum F_1^T(n) + \sum F_1^T(n_2),$$

$$R_1 = \{(R_1 + r^2 R_2)R + (R_2 + r^2 R_1)/R\}/E_0, \Omega_1 = \{(S_1 + r^2 S_2)R + (S_2 + r^2 S_1)/R\}/E_0, G_1 = \{(P_1 + r^2 P_2)R + (P_2 + r^2 P_1)/R\}/E_0, H_1 = \{(Q_1 + r^2 Q_2)R + (Q_2 + r^2 Q_1)/R\}/E_0$$

$$\sum = \{(K_1 + r^2 K_2)R + (K_2 + r^2 K_1)/R\}/E_0, \eta = \{(L_1 + r^2 L_2)R + (L_2 + r^2 L_1)/R\}/E_0, \rho = \{(M_1 + r^2 M_2)R + (M_2 + r^2 M_1)/R\}/E_0, \sum = \{(N_1 + r^2 N_2)R + (N_2 + r^2 N_1)/R\}/E_0$$

また、たねみ角、たねみモーメントおよび曲げモーメントと弾性曲面との周上の関数式に式(7)を代入すれば、板のたねみ角、たねみモーメントおよび曲げモーメントの各式がえられることになる。

(2) 基本連立方程式 辺AD, BCの各中間支柱の垂直変位をそれぞれ δ_{Rk}, δ_{Bk} とし、また、法線および接線方向の柱脚回転角を τ_{Rk}^A, τ_{Rk}^B および τ_{Bk}^A, τ_{Bk}^B とする($k=1, 2, \dots, f; l=1, 2, \dots, S$)。とすると、板の弾性曲面およびその一次微分係数 $\partial w/\partial r, \partial w/\partial \theta$ は各中間支柱位置において、これらの中間支柱の垂直変位および柱脚回転角に等しくなければならぬことより次の変形条件式を得る。

$$\begin{aligned} r = r_1, \quad \theta = \theta_{R1} \quad \text{で} \quad w = \delta_{R1}, \quad \partial w/\partial r = \tau_{R1}^A, \quad \partial w/\partial \theta = \tau_{R1}^A \quad (k=1, 2, \dots, f) \\ r = r_2, \quad \theta = \theta_{B1} \quad \text{で} \quad w = \delta_{B1}, \quad \partial w/\partial r = \tau_{B1}^B, \quad \partial w/\partial \theta = \tau_{B1}^B \quad (l=1, 2, \dots, S) \end{aligned} \quad (8)$$

式(8)に式(7)を代入し、適宜のうえ整理すれば、次のとき基本連立方程式がえられる。

$$\begin{bmatrix} A_{1k}^d & -B_{1k}^d & C_{1k}^d & -D_{1k}^d & E_{1k}^d & -F_{1k}^d \\ A_{1l}^d & -B_{1l}^d & C_{1l}^d & -D_{1l}^d & E_{1l}^d & -F_{1l}^d \\ A_{1k}^r & -B_{1k}^r & C_{1k}^r & -D_{1k}^r & E_{1k}^r & -F_{1k}^r \\ A_{1l}^r & -B_{1l}^r & C_{1l}^r & -D_{1l}^r & E_{1l}^r & -F_{1l}^r \\ A_{1k}^o & -B_{1k}^o & C_{1k}^o & -D_{1k}^o & E_{1k}^o & -F_{1k}^o \\ A_{1l}^o & -B_{1l}^o & C_{1l}^o & -D_{1l}^o & E_{1l}^o & -F_{1l}^o \end{bmatrix} \begin{bmatrix} \frac{1}{R_1} R_1^d \\ \frac{1}{R_2} R_2^d \\ \frac{1}{R_3} M_{R1}^A \\ \frac{1}{R_3} M_{R1}^B \\ \frac{1}{R_3} M_{B1}^A \\ \frac{1}{R_3} M_{B1}^B \end{bmatrix} = - \begin{bmatrix} G_{1k}^d + L_{1k}^d + J_{1k}^d + \frac{D}{R_1} \delta_{R1} \\ G_{1l}^d + L_{1l}^d + J_{1l}^d + \frac{D}{R_2} \delta_{B1} \\ G_{1k}^r + L_{1k}^r + J_{1k}^r + \frac{D}{R_3} \tau_{R1}^A \\ G_{1l}^r + L_{1l}^r + J_{1l}^r + \frac{D}{R_3} \tau_{B1}^B \\ G_{1k}^o + L_{1k}^o + J_{1k}^o + \frac{D}{R_3} \tau_{R1}^A \\ G_{1l}^o + L_{1l}^o + J_{1l}^o + \frac{D}{R_3} \tau_{B1}^B \end{bmatrix} \quad (9)$$

($k, l=1, 2, \dots, f$)
($j, l=1, 2, \dots, S$)

たゞし

$$A_{1k}^d = \frac{E}{R_1} \frac{4}{\pi \pi (\alpha \beta \lambda)} R_1^d \sin \frac{\pi \theta_0}{2} \sin \pi \theta_{R1} \sin \pi \theta_{R1}$$

$$B_{1k}^d = \frac{E}{R_1} \frac{4}{\pi \pi (\alpha \beta \lambda)} Q_1^d \sin \frac{\pi \theta_0}{2} \sin \pi \theta_{R1} \sin \pi \theta_{R1}$$

$$C_{1k}^d = \frac{E}{R_1} \frac{4}{\pi \pi (\alpha \beta \lambda)} G_1^d \sin \frac{\pi \theta_0}{2} \sin \pi \theta_{R1} \sin \pi \theta_{R1}$$

$$D_{1k}^d = \frac{E}{R_1} \frac{4}{\pi \pi (\alpha \beta \lambda)} H_1^d \sin \frac{\pi \theta_0}{2} \sin \pi \theta_{R1} \sin \pi \theta_{R1}$$

$$E_{1k}^d = \frac{E}{R_1} \frac{24}{\pi \pi (\alpha \beta \lambda)} R_1^d \left(\cos \frac{\pi \theta_0}{2} - \frac{2}{\pi \theta_0} \sin \frac{\pi \theta_0}{2} \right) \cos \pi \theta_{R1} \sin \pi \theta_{R1}$$

$$F_{1k}^d = \frac{E}{R_1} \frac{24}{\pi \pi (\alpha \beta \lambda)} Q_1^d \left(\cos \frac{\pi \theta_0}{2} - \frac{2}{\pi \theta_0} \sin \frac{\pi \theta_0}{2} \right) \cos \pi \theta_{R1} \sin \pi \theta_{R1}$$

$$A_{1k}^r = \frac{E}{R_1} \frac{4}{\pi \pi (\alpha \beta \lambda)} R_1^r \sin \frac{\pi \theta_0}{2} \sin \pi \theta_{R1} \sin \pi \theta_{R1}$$

$$B_{1k}^r = \frac{E}{R_1} \frac{4}{\pi \pi (\alpha \beta \lambda)} Q_1^r \sin \frac{\pi \theta_0}{2} \sin \pi \theta_{R1} \sin \pi \theta_{R1}$$

$$C_{1k}^r = \frac{E}{R_1} \frac{4}{\pi \pi (\alpha \beta \lambda)} G_1^r \sin \frac{\pi \theta_0}{2} \sin \pi \theta_{R1} \sin \pi \theta_{R1}$$

$$D_{1k}^r = \frac{E}{R_1} \frac{4}{\pi \pi (\alpha \beta \lambda)} H_1^r \sin \frac{\pi \theta_0}{2} \sin \pi \theta_{R1} \sin \pi \theta_{R1}$$

$$E_{1k}^r = \frac{E}{R_1} \frac{24}{\pi \pi (\alpha \beta \lambda)} R_1^r \left(\cos \frac{\pi \theta_0}{2} - \frac{2}{\pi \theta_0} \sin \frac{\pi \theta_0}{2} \right) \cos \pi \theta_{R1} \sin \pi \theta_{R1}$$

$$F_{1k}^r = \frac{E}{R_1} \frac{24}{\pi \pi (\alpha \beta \lambda)} Q_1^r \left(\cos \frac{\pi \theta_0}{2} - \frac{2}{\pi \theta_0} \sin \frac{\pi \theta_0}{2} \right) \cos \pi \theta_{R1} \sin \pi \theta_{R1}$$

$$A_{1k}^o = \frac{E}{R_1} \frac{4\alpha\lambda}{\pi \pi (\alpha \beta \lambda)} R_1^o \sin \frac{\pi \theta_0}{2} \sin \pi \theta_{R1} \cos \pi \theta_{R1}$$

$$B_{1k}^o = \frac{E}{R_1} \frac{4\alpha\lambda}{\pi \pi (\alpha \beta \lambda)} Q_1^o \sin \frac{\pi \theta_0}{2} \sin \pi \theta_{R1} \cos \pi \theta_{R1}$$

$$C_{1k}^o = \frac{E}{R_1} \frac{4\alpha\lambda}{\pi \pi (\alpha \beta \lambda)} G_1^o \sin \frac{\pi \theta_0}{2} \sin \pi \theta_{R1} \cos \pi \theta_{R1}$$

$$D_{1k}^o = \frac{E}{R_1} \frac{4\alpha\lambda}{\pi \pi (\alpha \beta \lambda)} H_1^o \sin \frac{\pi \theta_0}{2} \sin \pi \theta_{R1} \cos \pi \theta_{R1}$$

$$E_{1k}^o = \frac{E}{R_1} \frac{24\alpha\lambda}{\pi \pi (\alpha \beta \lambda)} R_1^o \left(\cos \frac{\pi \theta_0}{2} - \frac{2}{\pi \theta_0} \sin \frac{\pi \theta_0}{2} \right) \cos \pi \theta_{R1} \cos \pi \theta_{R1}$$

$$A_{1l}^d = \frac{E}{R_2} \frac{4}{\pi \pi (\alpha \beta \lambda)} R_2^d \sin \frac{\pi \theta_0}{2} \sin \pi \theta_{B1} \sin \pi \theta_{B1}$$

$$B_{1l}^d = \frac{E}{R_2} \frac{4}{\pi \pi (\alpha \beta \lambda)} Q_2^d \sin \frac{\pi \theta_0}{2} \sin \pi \theta_{B1} \sin \pi \theta_{B1}$$

$$C_{1l}^d = \frac{E}{R_2} \frac{4}{\pi \pi (\alpha \beta \lambda)} G_2^d \sin \frac{\pi \theta_0}{2} \sin \pi \theta_{B1} \sin \pi \theta_{B1}$$

$$D_{1l}^d = \frac{E}{R_2} \frac{4}{\pi \pi (\alpha \beta \lambda)} H_2^d \sin \frac{\pi \theta_0}{2} \sin \pi \theta_{B1} \sin \pi \theta_{B1}$$

$$E_{1l}^d = \frac{E}{R_2} \frac{24}{\pi \pi (\alpha \beta \lambda)} R_2^d \left(\cos \frac{\pi \theta_0}{2} - \frac{2}{\pi \theta_0} \sin \frac{\pi \theta_0}{2} \right) \cos \pi \theta_{B1} \sin \pi \theta_{B1}$$

$$F_{1l}^d = \frac{E}{R_2} \frac{24}{\pi \pi (\alpha \beta \lambda)} Q_2^d \left(\cos \frac{\pi \theta_0}{2} - \frac{2}{\pi \theta_0} \sin \frac{\pi \theta_0}{2} \right) \cos \pi \theta_{B1} \sin \pi \theta_{B1}$$

$$A_{1l}^r = \frac{E}{R_2} \frac{4}{\pi \pi (\alpha \beta \lambda)} R_2^r \sin \frac{\pi \theta_0}{2} \sin \pi \theta_{B1} \sin \pi \theta_{B1}$$

$$B_{1l}^r = \frac{E}{R_2} \frac{4}{\pi \pi (\alpha \beta \lambda)} Q_2^r \sin \frac{\pi \theta_0}{2} \sin \pi \theta_{B1} \sin \pi \theta_{B1}$$

$$C_{1l}^r = \frac{E}{R_2} \frac{4}{\pi \pi (\alpha \beta \lambda)} G_2^r \sin \frac{\pi \theta_0}{2} \sin \pi \theta_{B1} \sin \pi \theta_{B1}$$

$$D_{1l}^r = \frac{E}{R_2} \frac{4}{\pi \pi (\alpha \beta \lambda)} H_2^r \sin \frac{\pi \theta_0}{2} \sin \pi \theta_{B1} \sin \pi \theta_{B1}$$

$$E_{1l}^r = \frac{E}{R_2} \frac{24}{\pi \pi (\alpha \beta \lambda)} R_2^r \left(\cos \frac{\pi \theta_0}{2} - \frac{2}{\pi \theta_0} \sin \frac{\pi \theta_0}{2} \right) \cos \pi \theta_{B1} \sin \pi \theta_{B1}$$

$$F_{1l}^r = \frac{E}{R_2} \frac{24}{\pi \pi (\alpha \beta \lambda)} Q_2^r \left(\cos \frac{\pi \theta_0}{2} - \frac{2}{\pi \theta_0} \sin \frac{\pi \theta_0}{2} \right) \cos \pi \theta_{B1} \sin \pi \theta_{B1}$$

$$A_{1l}^o = \frac{E}{R_2} \frac{4\alpha\lambda}{\pi \pi (\alpha \beta \lambda)} R_2^o \sin \frac{\pi \theta_0}{2} \sin \pi \theta_{B1} \cos \pi \theta_{B1}$$

$$B_{1l}^o = \frac{E}{R_2} \frac{4\alpha\lambda}{\pi \pi (\alpha \beta \lambda)} Q_2^o \sin \frac{\pi \theta_0}{2} \sin \pi \theta_{B1} \cos \pi \theta_{B1}$$

$$C_{1l}^o = \frac{E}{R_2} \frac{4\alpha\lambda}{\pi \pi (\alpha \beta \lambda)} G_2^o \sin \frac{\pi \theta_0}{2} \sin \pi \theta_{B1} \cos \pi \theta_{B1}$$

$$D_{1l}^o = \frac{E}{R_2} \frac{4\alpha\lambda}{\pi \pi (\alpha \beta \lambda)} H_2^o \sin \frac{\pi \theta_0}{2} \sin \pi \theta_{B1} \cos \pi \theta_{B1}$$

$$E_{1l}^o = \frac{E}{R_2} \frac{24\alpha\lambda}{\pi \pi (\alpha \beta \lambda)} R_2^o \left(\cos \frac{\pi \theta_0}{2} - \frac{2}{\pi \theta_0} \sin \frac{\pi \theta_0}{2} \right) \cos \pi \theta_{B1} \cos \pi \theta_{B1}$$

