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フィレンデール型橋梁の解法

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SOLUTION OF THE VIERENDEEL TYPE BRIDGES

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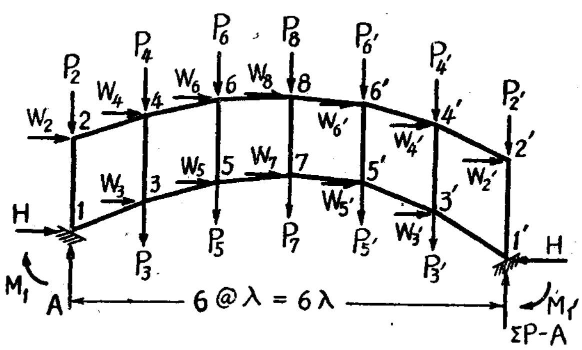
Synopsis The author solves the load and temperature stresses of spandrel braced Vierendeel type bridges by slope deflection method. The simultaneous equations from which the stresses are worked out can be mechanically tabulated, and these equations can be applied to all Vierendeel type bridges such as arch and truss bridges of Vierendeel type.

要旨 スパンドレルブレース型のフィレンデール橋梁の荷重及び温度応力を撓角法を用いて解いたもので，荷重応力に関しては部材の伸縮を考慮している。応力を求めるための連立方程式は表示して機械的な作表を可能にし，又アーチ橋，トラス橋等あらゆる型のフィレンデール橋梁に対してこの連立方程式が適用出来る事を示した。

1. 序　　言

図—1 のような上下弦材とも曲つている一般的なフィレンデール型固定アーチ橋を考える。格間の数は説明の便宜のため6個とする。部材の伸縮が，端モーメント M_{ab} を求める次の (I) 式に及ぼす影響は極めて小さいので，この (I) 式を基本式として使用する。

図—1



$$M_{ab}=K_{ab}(2\varphi_a+\varphi_b+\mu_{ab}) \quad \cdots\cdots(\text{I})$$

2. 格間4辺形の幾何学的釣合

4辺形 $(r-1)r(r+2)(r+1)$ が変形後 $(r-1)'r'(r+2)'(r+1)'$ に移つたとする (図—2)。

l, l': それぞれ変形前後における部材の長さ

Δl: 変形前後における部材の長さの差(伸＋，縮－)

θ, θ': それぞれ変形前後における部材の水平となす角度

ψ: 部材回転角

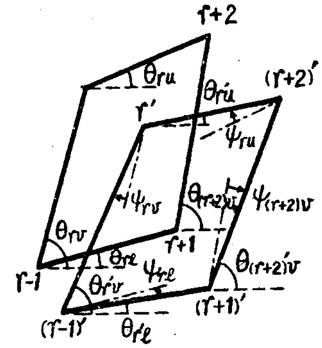
N: 部材の軸力

E: 材料の弾性係数

ε: 材料の膨脹係数

t: 部材の温度変化量

図—2



添字 rl, ru, rv, $(r+2)v$ はそれぞれ部材 $(r-1)(r+1)$, $r(r+2)$, $(r-1)r$, $(r+1)(r+2)$ を意味する。変形前後において4辺形は何れも閉じている故

$$\Sigma l\cos\theta=0, \quad \Sigma l\sin\theta=0$$

$$\Sigma l'\cos\theta'=0, \quad \Sigma l'\sin\theta'=0$$

然るに $l'=l+\Delta l$, $\theta'=\theta-\psi$

$$\therefore \quad \Sigma l'\cos\theta'=\Sigma(l\cos\theta\cos\psi+l\sin\theta\sin\psi+\Delta l\cos\theta\cos\psi+\Delta l\sin\theta\sin\psi)=0$$

$$\Sigma l'\sin\theta'=\Sigma(l\sin\theta\cos\psi-l\cos\theta\sin\psi+\Delta l\sin\theta\cos\psi-\Delta l\cos\theta\sin\psi)=0$$

ψ は極めて小さいから $\sin\psi=\psi$, $\cos\psi=1$ とおき，更に $\Sigma\Delta l\psi\sin\theta$ 及び $\Sigma\Delta l\psi\cos\theta$ は2次の微小量であるから

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[illegible]れば　$\Sigma l\mu\sin\theta+\Sigma\Delta l\cos\theta=0$

$$-\Sigma l\mu\cos\theta+\Sigma\Delta l\sin\theta=0$$

[illegible]辺に $-6E$ を乗じ，$\Delta l=\dfrac{N}{EA}l+\varepsilon tl$ を入れれば

$$\Sigma l\mu\sin\theta-6\Sigma\frac{N}{A}l\cos\theta-6\Sigma E\varepsilon tl\cos\theta=0$$

$$\Sigma l\mu\cos\theta+6\Sigma\frac{N}{A}l\sin\theta+6\Sigma E\varepsilon tl\sin\theta=0$$

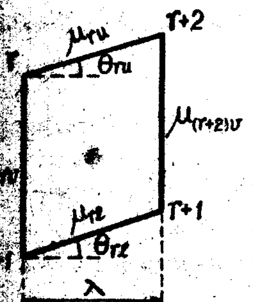
[illegible]場合，各部材の材料，温度変化量ともに同一と考える。部材毎に材料，温度変化量異なる場合についても同[illegible]く事が出来る。

[illegible]及び t は一定，$\Sigma l\cos\theta=0$，$\Sigma l\sin\theta=0$ なる故，前式は次のようになる。

$$\left.\begin{aligned}\Sigma l\mu\sin\theta-6\Sigma\frac{N}{A}l\cos\theta=0\\ \Sigma l\mu\cos\theta+6\Sigma\frac{N}{A}l\sin\theta=0\end{aligned}\right\}\quad\cdots\cdots\cdots\cdots(\text{II})$$

[illegible]式を図—1の任意の格間に適用すれば(図—3)，橋の左半分に対して次の２式を得る。

図—3



$$\mu_{rv}=\frac{l_{(r+1)(r+2)}}{l_{(r-1)r}}\mu_{(r+2)v}+\frac{\lambda}{l_{(r-1)r}}\tan\theta_{rl}\mu_{rl}-\frac{\lambda}{l_{(r-1)r}}\tan\theta_{ru}\mu_{ru}$$

$$-6\frac{\lambda}{l_{(r-1)r}}\left\{\frac{N_{(r-1)(r+1)}}{A_{(r-1)(r+1)}}-\frac{N_{r(r+2)}}{A_{r(r+2)}}\right\}\quad\cdots\cdots\cdots\cdots(\text{III})$$

$$\mu_{rl}-\mu_{ru}+6\left\{\frac{N_{(r-1)(r+1)}}{A_{(r-1)(r+1)}}\tan\theta_{rl}+\frac{N_{(r+1)(r+2)}}{A_{(r+1)(r+2)}}\quad\frac{l_{(r+1)(r+2)}}{\lambda}\right.$$

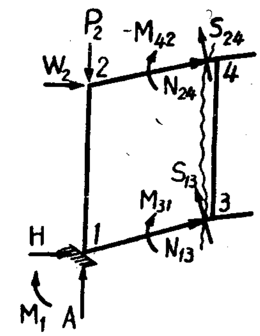
$$\left.-\frac{N_{r(r+2)}}{A_{r(r+2)}}\tan\theta_{ru}-\frac{N_{(r-1)r}}{A_{(r-1)r}}\quad\frac{l_{(r-1)r}}{\lambda}\right\}=0\quad\cdots\cdots\cdots\cdots(\text{IV})$$

橋の右半分に対しても同様な式を得る。

3. 軸　　力

節点３及び４の直ぐ左側に図—4のような断面を仮定し，この断面より左[illegible]釣合を考える。先づ節点４のまわりのモーメントの釣合を考えて整理すれ[illegible] N_{13} は次のように各未知数，荷重 P, W 及び Φ_1 の函数として表わす事が[illegible]る。Φ_1 は支点１における節点回転角を$2E$倍したもので，構造が不備なた[illegible]点が回転した場合に適用出来るようにしたもので，既知の値とする。

図—4



$$N_{13}=F(\varphi_2,\varphi_3,\varphi_4,\mu_{2l},\mu_{2u},M_1,H,A,P_2,W_2,\Phi_1)$$

[illegible]に節点３のまわりのモーメントの釣合を考えれば

$$N_{24}=F(\varphi_2,\varphi_3,\varphi_4,\mu_{2l},\mu_{2u},M_1,H,A,P_2,W_2,\Phi_1)$$

[illegible]に弦材 $(r-1,r+1)$，$(r,r+2)$ に対して節点 $r+1$ 及び $r+2$ の直ぐ左側[illegible]と同様な断面を仮定して，この断面より左側の釣合を考えれば，下弦材 $(r-1,r+1)$ 及び上弦材 $(r,r+2)$ に対する軸力は次のような形で求まる。

$$N_{(r-1)(r+1)}=F(\varphi_{r-1},\varphi_r,\varphi_{r+1},\varphi_{r+2},\mu_{rl},\mu_{ru},M_1,H,A,P_2,P_3,\cdots\cdots,P_r,W_2,W_3,\cdots\cdots,W_r)$$

$$N_{r(r+2)}=F(\varphi_{r-1},\varphi_r,\varphi_{r+1},\varphi_{r+2},\mu_{rl},\mu_{ru},M_1,H,A,P_2,P_3,\cdots\cdots,P_r,W_2,W_3,\cdots\cdots,W_r)$$

[illegible]材に対しては，一般に r 節点に作用する力の垂直分力の釣合を考えれば次式を得る。

$$N_{(r-1)r}=F(\varphi_{r-3},\varphi_{r-2},\varphi_{r-1},\varphi_r,\varphi_{r+1},\varphi_{r+2},\mu_{(r-2)l},\mu_{rl},\mu_{(r-2)u},\mu_{ru},M_1,H,A,P_2,P_3,\cdots\cdots,P_r,W_2,W_3,\cdots\cdots,W_r)$$

[illegible]の右半分に対しても同様に軸力を得る。

4. 垂直材の μ

[illegible]で求めた N の値を (III) 式に入れれば，μ_{rv} は次のような形で表わせる。

$$\mu_{rv}=F(\mu_{(r+2)v},\varphi_{r-1},\varphi_r,\varphi_{r+1},\varphi_{r+2},\mu_{rl},\mu_{ru},M_1,H,A,P_2,P_3,\cdots\cdots P_r,W_2,W_3,\cdots\cdots,W_r)$$

[illegible]式を格間 5—7$(r=6)$，3—5$(r=4)$，1—3$(r=2)$に順次適用してゆけば，垂直材 (5,6)，(3,4)，(1,2) の μ 即[illegible] μ_{6v}，μ_{4v}，μ_{2v} を中央垂直材の μ {この場合垂直材 (7,8) の μ}，弦材の μ, φ, M_1, H, A 及び荷重 P, W で

表わす事が出来る。

橋の右半分に対しても同様である。即ち未知数としての垂直材の μ は中央垂直材の μ のみとなり，未知数は此の例においては6個を減ずる事になる。

5. 方程式の作製（表—1）

（A） 節点釣合方程式

節点1において $M_{12}=K_{12}(2\Phi_1+\varphi_2+\mu_{2v})$，$M_{13}=K_{13}(2\Phi_1+\varphi_3+\mu_{2l})$，$M_1+M_{12}+M_{13}=0$ より（1）式を得

表—1　連立方程式表

Table of Simultaneous Equations

式	[Mi]	[Mi']	φ_2	$\varphi_{2'}$	φ_3	$\varphi_{3'}$	φ_4	$\varphi_{4'}$	φ_5	$\varphi_{5'}$	φ_6	$\varphi_{6'}$	φ_7	φ_8	μ_{2l}	$\mu_{2'l}$	μ_{2u}	$\mu_{2'u}$	μ_{4l}	$\mu_{4'l}$	μ_{4u}	$\mu_{4'u}$	μ_{6l}	$\mu_{6'l}$	μ_{6u}	$\mu_{6'u}$	μ_v	[H]	[A]	右辺
(1)	$j_1+\nabla_2$		$K_{12}+\bar{C}_{2(2)}$		$K_{13}+\bar{B}_{4(2)}$		$C_{4(2)}$		$B_{6(2)}$		$C_{6(2)}$		$B_{8(2)}$	$C_{8(2)}$	$K_{13}+D_{2(2)}$		$E_{2(2)}$		$D_{4(2)}$		$E_{4(2)}$		$D_{6(2)}$		$E_{6(2)}$		F_2	G_2	I_2	$\alpha_2+\beta_2-(j_1+\bar{B}_{2(2)})\Phi_1$
(2)		$j_{1'}+\nabla_{2'}$		$K_{1'2'}+\bar{C}_{2'(2')}$		$K_{1'3'}+\bar{B}_{4'(2')}$		$C_{4'(2')}$		$B_{6'(2')}$		$C_{6'(2')}$	$B_{8'(2')}$	$C_{8'(2')}$		$K_{1'3'}+D_{2'(2')}$		$E_{2'(2')}$		$D_{4'(2')}$		$E_{4'(2')}$		$D_{6'(2')}$		$E_{6'(2')}$	$F_{2'}$	$-G_{2'}$	$I_{2'}$	$-\alpha_{2'}+\beta_{2'}+I_{2'}\Sigma P-(j_{1'}+\bar{B}_{2'(2')})\Phi_{1'}$
(3)	∇_2		$j_2+\bar{C}_{2(2)}$		$B_{4(2)}$		$K_{24}+C_{4(2)}$		$B_{6(2)}$		$C_{6(2)}$		$B_{8(2)}$	$C_{8(2)}$	$D_{2(2)}$		$K_{24}+E_{2(2)}$		$D_{4(2)}$		$E_{4(2)}$		$D_{6(2)}$		$E_{6(2)}$		F_2	G_2	I_2	$\alpha_2+\beta_2-(K_{12}+\bar{B}_{2(2)})\Phi_1$
(4)		$\nabla_{2'}$		$j_{2'}+\bar{C}_{2'(2')}$		$B_{4'(2')}$		$K_{2'4'}+C_{4'(2')}$		$B_{6'(2')}$		$C_{6'(2')}$	$B_{8'(2')}$	$C_{8'(2')}$		$D_{2'(2')}$		$K_{2'4'}+E_{2'(2')}$		$D_{4'(2')}$		$E_{4'(2')}$		$D_{6'(2')}$		$E_{6'(2')}$	$F_{2'}$	$-G_{2'}$	$I_{2'}$	$-\alpha_{2'}+\beta_{2'}+I_{2'}\Sigma P-(K_{1'2'}+\bar{B}_{2'(2')})\Phi_{1'}$
(5)	∇_4				$j_3+\bar{B}_{4(4)}$		$K_{34}+\bar{C}_{4(4)}$		$K_{35}+B_{6(4)}$		$C_{6(4)}$		$B_{8(4)}$	$C_{8(4)}$	K_{13}				$K_{35}+D_{4(4)}$		$E_{4(4)}$		$D_{6(4)}$		$E_{6(4)}$		F_4	G_4	I_4	$\alpha_4+\beta_4-K_{13}I_1$
(6)		$\nabla_{4'}$				$j_{3'}+\bar{B}_{4'(4')}$		$K_{3'4'}+\bar{C}_{4'(4')}$		$K_{3'5'}+B_{6'(4')}$		$C_{6'(4')}$	$B_{8'(4')}$	$C_{8'(4')}$		$K_{1'3'}$				$K_{3'5'}+D_{4'(4')}$		$E_{4'(4')}$		$D_{6'(4')}$		$E_{6'(4')}$	$F_{4'}$	$-G_{4'}$	$I_{4'}$	$-\alpha_{4'}+\beta_{4'}+I_{4'}\Sigma P-K_{1'3'}\Phi_{1'}$
(7)	∇_4		K_{24}		$K_{34}+\bar{B}_{4(4)}$		$j_4+\bar{C}_{4(4)}$		$B_{6(4)}$		$K_{46}+C_{6(4)}$		$B_{8(4)}$	$C_{8(4)}$			K_{24}		$D_{4(4)}$		$K_{46}+E_{4(4)}$		$D_{6(4)}$		$E_{6(4)}$		F_4	G_4	I_4	$\alpha_4+\beta_4$
(8)		$\nabla_{4'}$		$K_{2'4'}$		$K_{3'4'}+\bar{B}_{4'(4')}$		$j_{4'}+\bar{C}_{4'(4')}$		$B_{6'(4')}$		$K_{4'6'}+C_{6'(4')}$	$B_{8'(4')}$	$C_{8'(4')}$				$K_{2'4'}$		$D_{4'(4')}$		$K_{4'6'}+E_{4'(4')}$		$D_{6'(4')}$		$E_{6'(4')}$	$F_{4'}$	$-G_{4'}$	$I_{4'}$	$-\alpha_{4'}+\beta_{4'}+I_{4'}\Sigma P$
(9)	∇_6				K_{35}				$j_5+\bar{B}_{6(6)}$		$K_{56}+\bar{C}_{6(6)}$		$K_{57}+B_{8(6)}$	$C_{8(6)}$					K_{35}				$K_{57}+D_{6(6)}$		$E_{6(6)}$		F_6	G_6	I_6	$\alpha_6+\beta_6$
(10)		$\nabla_{6'}$				$K_{3'5'}$				$j_{5'}+\bar{B}_{6'(6')}$		$K_{5'6'}+\bar{C}_{6'(6')}$	$K_{5'7'}+B_{8'(6')}$	$C_{8'(6')}$						$K_{3'5'}$				$K_{5'7'}+D_{6'(6')}$		$E_{6'(6')}$	$F_{6'}$	$-G_{6'}$	$I_{6'}$	$-\alpha_{6'}+\beta_{6'}+I_{6'}\Sigma P$
(11)	∇_6						K_{46}		$K_{56}+\bar{B}_{6(6)}$		$j_6+\bar{C}_{6(6)}$		$B_{8(6)}$	$K_{68}+C_{8(6)}$							K_{46}		$D_{6(6)}$		$K_{68}+E_{6(6)}$		F_6	G_6	I_6	$\alpha_6+\beta_6$
(12)		$\nabla_{6'}$						$K_{4'6'}$		$K_{5'6'}+\bar{B}_{6'(6')}$		$j_{6'}+\bar{C}_{6'(6')}$	$B_{8'(6')}$	$K_{6'8'}+C_{8'(6')}$								$K_{4'6'}$		$D_{6'(6')}$		$K_{6'8'}+E_{6'(6')}$	$F_{6'}$	$-G_{6'}$	$I_{6'}$	$-\alpha_{6'}+\beta_{6'}+I_{6'}\Sigma P$
(13)									K_{57}	$K_{5'7'}$			j_7	K_{78}									K_{57}	$K_{5'7'}$			F_8			0
(14)											K_{68}	$K_{6'8'}$	K_{78}	j_8											K_{68}	$K_{6'8'}$	F_8			0
(15)	$\bar{U}_2$		Q_{2u}		R_{2l}		R_{2u}								L_{2l}		L_{2u}											T_2	S_2	$\gamma_2+\delta_2-Q_{2l}\Phi_1$
(16)		$\bar{U}_{2'}$		$Q_{2'u}$		$R_{2'l}$		$R_{2'u}$								$L_{2'l}$		$L_{2'u}$										$-T_{2'}$	$S_{2'}$	$-\gamma_{2'}+\delta_{2'}+S_{2'}\Sigma P-Q_{2'l}\Phi_{1'}$
(17)	$\bar{U}_4$				Q_{4l}		Q_{4u}		R_{4l}		R_{4u}								L_{4l}		L_{4u}							T_4	S_4	$\gamma_4+\delta_4$
(18)		$\bar{U}_{4'}$				$Q_{4'l}$		$Q_{4'u}$		$R_{4'l}$		$R_{4'u}$								$L_{4'l}$		$L_{4'u}$						$-T_{4'}$	$S_{4'}$	$-\gamma_{4'}+\delta_{4'}+S_{4'}\Sigma P$
(19)	$\bar{U}_6$								Q_{6l}		Q_{6u}		R_{6l}	R_{6u}									L_{6l}		L_{6u}			T_6	S_6	$\gamma_6+\delta_6$
(20)		$\bar{U}_{6'}$								$Q_{6'l}$		$Q_{6'u}$	$R_{6'l}$	$R_{6'u}$										$L_{6'l}$		$L_{6'u}$		$-T_{6'}$	$S_{6'}$	$-\gamma_{6'}+\delta_{6'}+S_{6'}\Sigma P$
(21)	i_2		b_{2u}		c_{2l}		c_{2u}		d_{2l}		d_{2u}				f_{2l}		f_{2u}		g_{2l}		g_{2u}							h_2	k_2	$\varepsilon_2+\varsigma_2-b_{2l}\Phi_1$
(22)		$i_{2'}$		$b_{2'u}$		$c_{2'l}$		$c_{2'u}$		$d_{2'l}$		$d_{2'u}$				$f_{2'l}$		$f_{2'u}$		$g_{2'l}$		$g_{2'u}$						$-h_{2'}$	$k_{2'}$	$-\varepsilon_{2'}+\varsigma_{2'}+k_{2'}\Sigma P-b_{2'l}\Phi_{1'}$
(23)	i_4		a_{4u}		b_{4l}		b_{4u}		c_{4l}		c_{4u}		d_{4l}	d_{4u}	e_{4l}		e_{4u}		f_{4l}		f_{4u}		g_{4l}		g_{4u}			h_4	k_4	$\varepsilon_4+\varsigma_4-a_{4l}\Phi_1$
(24)		$i_{4'}$		$a_{4'u}$		$b_{4'l}$		$b_{4'u}$		$c_{4'l}$		$c_{4'u}$	$d_{4'l}$	$d_{4'u}$		$e_{4'l}$		$e_{4'u}$		$f_{4'l}$		$f_{4'u}$		$g_{4'l}$		$g_{4'u}$		$-h_{4'}$	$k_{4'}$	$-\varepsilon_{4'}+\varsigma_{4'}+k_{4'}\Sigma P-a_{4'l}\Phi_{1'}$
(25)	i_6				a_{6l}		a_{6u}		b_{6l}	d_{6l}	b_{6u}	d_{6u}	c_{6l}	c_{6u}					e_{6l}		e_{6u}		f_{6l}	g_{6l}	f_{6u}	g_{6u}		h_6	k_6	$\varepsilon_6+\varsigma_6$
(26)		$i_{6'}$				$a_{6'l}$		$a_{6'u}$	$d_{6'l}$	$b_{6'l}$	$d_{6'u}$	$b_{6'u}$	$c_{6'l}$	$c_{6'u}$						$e_{6'l}$		$e_{6'u}$	$g_{6'l}$	$f_{6'l}$	$g_{6'u}$	$f_{6'u}$		$-h_{6'}$	$k_{6'}$	$-\varepsilon_{6'}+\varsigma_{6'}+k_{6'}\Sigma P$
(27)	w_r	$w_{r'}$	m_{2u}	$m_{2'u}$	m_{4l}	$m_{4'l}$	m_{4u}	$m_{4'u}$	m_{6l}	$m_{6'l}$	m_{6u}	$m_{6'u}$	$\mathring{m}_{8l}$	$\mathring{m}_{8u}$	n_{2l}	$n_{2'l}$	n_{2u}	$n_{2'u}$	n_{4l}	$n_{4'l}$	n_{4u}	$n_{4'u}$	n_{6l}	$n_{6'l}$	n_{6u}	$n_{6'u}$	Z	u	$v_r+v_{r'}$	$\eta+\nu+v_r\Sigma P-m_{2l}\Phi_1-m_{2'l}\Phi_{1'}$
(28)	$-x_r$	$x_{r'}$	$-p_{2u}$	$p_{2'u}$	$-p_{4l}$	$p_{4'l}$	$-p_{4u}$	$p_{4'u}$	$-p_{6l}$	$p_{6'l}$	$-p_{6u}$	$p_{6'u}$	$-p_{8l}+p_{8'l}$	$-p_{8u}+p_{8'u}$	$-q_{2l}$	$q_{2'l}$	$-q_{2u}$	$q_{2'u}$	$-q_{4l}$	$q_{4'l}$	$-q_{4u}$	$q_{4'u}$	$-q_{6l}$	$q_{6'l}$	$-q_{6u}$	$q_{6'u}$		s	$-t_r+t_{r'}$	$\xi+\rho+t_{r'}\Sigma P+p_{2l}\Phi_1-p_{2'l}\Phi_{1'}+E(6\Sigma t-$ [illegible]$)$
(29)	$\bar{x}_r$	$\bar{x}_{r'}$	$\bar{p}_{2u}$	$\bar{p}_{2'u}$	$\bar{p}_{4l}$	$\bar{p}_{4'l}$	$\bar{p}_{4u}$	$\bar{p}_{4'u}$	$\bar{p}_{6l}$	$\bar{p}_{6'l}$	$\bar{p}_{6u}$	$\bar{p}_{6'u}$	$\bar{p}_{8l}+\bar{p}_{8'l}$	$\bar{p}_{8u}+\bar{p}_{8'u}$	$\bar{q}_{2l}$	$\bar{q}_{2'l}$	$\bar{q}_{2u}$	$\bar{q}_{2'u}$	$\bar{q}_{4l}$	$\bar{q}_{4'l}$	$\bar{q}_{4u}$	$\bar{q}_{4'u}$	$\bar{q}_{6l}$	$\bar{q}_{6'l}$	$\bar{q}_{6u}$	$\bar{q}_{6'u}$		$\bar{s}$	$\bar{t}_r+\bar{t}_{r'}$	$\bar{\xi}+\bar{\rho}+\bar{t}_{r'}\Sigma P-\bar{p}_{2l}\Phi_1-\bar{p}_{2'l}\Phi_{1'}+E$ [illegible]

る。

節点 1′, 2, 2′, ……, 7, 8 の各節点に対しても同様に考えて（2）〜（14）式を得る。尚未知数 $[M_1]$, $[M_1']$, $[H]$, $[A]$ の [ ] はディメンションを φ, μ に合わせるためのものである。各記号の意味は次の通りである（水平反力 W に対する項 β_r は長くなるので紙面の都合で省略する。以下の W に対する項 $\delta_r, \zeta_r, \nu, \rho, \bar{\rho}$ についても同じ）。

$j_r=2\times$（節点 r に集まる部材の K の総和）

$$V_r=6\frac{K_{(r-1)r}}{l_{(r-1)r}}\lambda\left\{\frac{1}{l_{(r+1)(r+2)}}\left(\frac{1}{A_{(r-1)(r+1)}\cos\theta_{rl}}+\frac{1}{A_{r(r+2)}\cos\theta_{ru}}\right)\right.$$
$$+\frac{1}{l_{(r+3)(r+4)}}\left(\frac{1}{A_{(r+1)(r+3)}\cos\theta_{(r+2)l}}+\frac{1}{A_{(r+2)(r+4)}\cos\theta_{(r+2)u}}\right)$$
$$\left.+\cdots\cdots+\frac{1}{l_{(n+1)(n+2)}}\left(\frac{1}{A_{(n-1)(n+1)}\cos\theta_{nl}}+\frac{1}{A_{n(n+2)}\cos\theta_{nu}}\right)\right\}$$

$$B_{r(x)}=-6\frac{K_{(x-1)x}}{l_{(x-1)x}}\lambda\left\{2\frac{K_{(r-3)(r-1)}}{l_{(r-1)r}}\left(\frac{1}{A_{(r-3)(r-1)}\cos\theta_{(r-2)l}}+\frac{1}{A_{(r-2)r}\cos\theta_{(r-2)u}}\right)\right.$$
$$+\frac{K_{(r-1)(r+1)}}{l_{(r+1)(r+2)}}\left(\frac{1}{A_{\text{[illegible]}(r+1)}\cos\theta_{rl}}+\frac{1}{A_{r(r+2)}\cos\theta_{ru}}\right)+\frac{3}{\lambda}\left(\frac{K_{(r-3)(r-1)}}{A_{(r-3)(r-1)}}\sin\theta_{(r-2)l}\right.$$

$$+\frac{K_{(r-1)(r+1)}}{A_{(r-1)(r+1)}}\sin\theta_{rl}\Big)\Big\}$$

$$\bar{B}_{r(x)}=-6\frac{K_{(x-1)x}}{l_{(x-1)x}}\lambda\left\{\frac{K_{(r-1)(r+1)}}{l_{(r+1)(r+2)}}\left(\frac{1}{A_{(r-1)(r+1)}\cos\theta_{rl}}+\frac{1}{A_{r(r+2)}\cos\theta_{ru}}\right)+\frac{3}{\lambda}\frac{K_{(r-1)(r+1)}}{A_{(r-1)(r+1)}}\sin\theta_{rl}\right\}$$

$$C_{r(x)}=-6\frac{K_{(x-1)x}}{l_{(x-1)x}}\lambda\Big\{2\frac{K_{(r-2)r}}{l_{(r-1)r}}\left(\frac{1}{A_{(r-3)(r-1)}\cos\theta_{(r-2)l}}+\frac{1}{A_{(r-2)r}\cos\theta_{(r-2)u}}\right)$$

$$+\frac{K_{r(r+2)}}{l_{(r+1)(r+2)}}\left(\frac{1}{A_{(r-1)(r+1)}\cos\theta_{rl}}+\frac{1}{A_{r(r+2)}\cos\theta_{ru}}\right)-\frac{3}{\lambda}\Big(\frac{K_{(r-2)r}}{A_{(r-2)r}}\sin\theta_{(r-2)u}$$

$$+\frac{K_{r(r+2)}}{A_{r(r+2)}}\sin\theta_{ru}\Big)\Big\}$$

$$\bar{C}_{r(x)}=-6\frac{K_{(x-1)x}}{l_{(x-1)x}}\lambda\left\{\frac{K_{r(r+2)}}{l_{(r+1)(r+2)}}\left(\frac{1}{A_{(r-1)(r+1)}\cos\theta_{rl}}+\frac{1}{A_{r(r+2)}\cos\theta_{ru}}\right)-\frac{3}{\lambda}\frac{K_{r(r+2)}}{A_{r(r+2)}}\sin\theta_{ru}\right\}$$

$$D_{r(x)}=\frac{K_{(x-1)x}}{l_{(x-1)x}}\lambda\Big[\tan\theta_{rl}-6\Big\{\frac{K_{(r-1)(r+1)}}{l_{(r+1)(r+2)}}\left(\frac{1}{A_{(r-1)(r+1)}\cos\theta_{rl}}+\frac{1}{A_{r(r+2)}\cos\theta_{ru}}\right)$$

$$+\frac{2}{\lambda}\frac{K_{(r-1)(r+1)}}{A_{(r-1)(r+1)}}\sin\theta_{rl}\Big\}\Big]$$

$$E_{r(x)}=-\frac{K_{(x-1)x}}{l_{(x-1)x}}\lambda\Big[\tan\theta_{ru}+6\Big\{\frac{K_{r(r+2)}}{l_{(r+1)(r+2)}}\left(\frac{1}{A_{(r-1)(r+1)}\cos\theta_{rl}}+\frac{1}{A_{r(r+2)}\cos\theta_{ru}}\right)$$

$$-\frac{2}{\lambda}\frac{K_{r(r+2)}}{A_{r(r+2)}}\sin\theta_{ru}\Big\}\Big]$$

$$F_r=\frac{K_{(r-1)r}}{l_{(r-1)r}}l_{(n+1)(n+2)}$$

$$G_r=6\frac{K_{(r-1)r}}{l_{(r-1)r}}\lambda\Big\{\frac{1}{A_{(r-1)(r+1)}\cos\theta_{rl}}+\frac{1}{A_{(r+1)(r+3)}\cos\theta_{(r+2)l}}+\cdots\cdots+\frac{1}{A_{(n-1)(n+1)}\cos\theta_{nl}}$$

$$+\frac{\lambda}{l_{(r+1)(r+2)}}\left(\frac{1}{A_{(r-1)(r+1)}\cos\theta_{rl}}+\frac{1}{A_{r(r+2)}\cos\theta_{ru}}\right)(\tan\theta_{2l}+\tan\theta_{4l}+\cdots\cdots+\tan\theta_{rl})$$

$$+\frac{\lambda}{l_{(r+3)(r+4)}}\left(\frac{1}{A_{(r+1)(r+3)}\cos\theta_{(r+2)l}}+\frac{1}{A_{(r+2)(r+4)}\cos\theta_{(r+2)u}}\right)(\tan\theta_{2l}+\tan\theta_{4l}+\cdots\cdots$$

$$+\tan\theta_{(r+2)l})+\cdots\cdots+\frac{\lambda}{l_{(n+1)(n+2)}}\left(\frac{1}{A_{(n-1)(n+1)}\cos\theta_{nl}}+\frac{1}{A_{n(n+2)}\cos\theta_{nu}}\right)$$

$$\times(\tan\theta_{2l}+\tan\theta_{4l}+\cdots\cdots+\tan\theta_{nl})\Big\}$$

$$I_r=-6\frac{K_{(r-1)r}}{l_{(r-1)r}}\lambda^2\Big\{\frac{\frac{r}{2}}{l_{(r+1)(r+2)}}\left(\frac{1}{A_{(r-1)(r+1)}\cos\theta_{rl}}+\frac{1}{A_{r(r+2)}\cos\theta_{ru}}\right)+\frac{\frac{r}{2}+1}{l_{(r+3)(r+4)}}$$

$$\times\left(\frac{1}{A_{(r+1)(r+3)}\cos\theta_{(r+2)l}}+\frac{1}{A_{(r+2)(r+4)}\cos\theta_{(r+2)u}}\right)+\cdots\cdots+\frac{\frac{n}{2}}{l_{(n+1)(n+2)}}\Big(\frac{1}{A_{(n-1)(n+1)}\cos\theta_{nl}}$$

$$+\frac{1}{A_{n(n+2)}\cos\theta_{nu}}\Big)\Big\}$$

$$\alpha_r=-6\frac{K_{(r-1)r}}{l_{(r-1)r}}\lambda^2\Big\{\frac{\frac{r}{2}}{l_{(r+1)(r+2)}}\left(\frac{1}{A_{(r-1)(r+1)}\cos\theta_{rl}}+\frac{1}{A_{r(r+2)}\cos\theta_{ru}}\right)+\frac{\frac{r}{2}+1}{l_{(r+3)(r+4)}}$$

$$\times\left(\frac{1}{A_{(r+1)(r+3)}\cos\theta_{(r+2)l}}+\frac{1}{A_{(r+2)(r+4)}\cos\theta_{(r+2)u}}\right)+\cdots\cdots+\frac{\frac{n}{2}}{l_{(n+1)(n+2)}}\Big(\frac{1}{A_{(n-1)(n+1)}\cos\theta_{nl}}$$

$$+\frac{1}{A_{n(n+2)}\cos\theta_{nu}}\Big)\Big\}P_2-6\frac{K_{(r-1)r}}{l_{(r-1)r}}\lambda^2\Big\{\frac{\frac{r}{2}-1}{l_{(r+1)(r+2)}}\Big(\frac{1}{A_{(r-1)(r+1)}\cos\theta_{rl}}$$

$$+\frac{1}{A_{r(r+2)}\cos\theta_{ru}}\Big)+\frac{\frac{r}{2}}{l_{(r+3)(r+4)}}\left(\frac{1}{A_{(r+1)(r+3)}\cos\theta_{(r+2)l}}+\frac{1}{A_{(r+2)(r+4)}\cos\theta_{(r+2)u}}\right)$$

$$+\cdots\cdots+\frac{\frac{n}{2}-1}{l_{(n+1)(n+2)}}\left(\frac{1}{A_{(n-1)(n+1)}\cos\theta_{nl}}+\frac{1}{A_{n(n+2)}\cos\theta_{nu}}\right)\Big\}(P_3+P_4)-\cdots\cdots\cdots$$

$$-6\frac{K_{(r-1)r}}{l_{(r-1)r}}\lambda^2\left\{\frac{1}{l_{(n+1)(n+2)}}\left(\frac{1}{A_{(n-1)(n+1)}\cos\theta_{nl}}+\frac{1}{A_{n(n+2)}\cos\theta_{nu}}\right)\right\}(P_{n-1}+P_n)$$

(B) 断面釣合方程式

図―4 において節点3及び4の直ぐ左側に仮定した断面より左側の力の垂直分力の釣合を考えて

$$N_{13}\sin\theta_{2l}+N_{24}\sin\theta_{2u}+S_{13}\cos\theta_{2l}+S_{24}\cos\theta_{2u}+A-P_2=0$$

之に 3. で求めた N_{13}, N_{24} を入れ，S_{13}, S_{24} を φ, μ で表わして整理すれば (15) 式を得る。同様に節点 3′ 及び 4′ の直ぐ右側，節点5及び6の直ぐ左側，節点5′ 及び 6′ の直ぐ右側等の断面に対する釣合を考えれば (16)～(20) 式を得る。

$$U_r=-(\tan\theta_{rl}-\tan\theta_{ru})$$

$$Q_{rl}=K_{(r-1)(r+1)}\left\{(\tan\theta_{rl}-\tan\theta_{ru})+3\frac{l_{(r+1)(r+2)}}{\lambda}\right\}$$

$$Q_{ru}=K_{r(r+2)}\left\{(\tan\theta_{rl}-\tan\theta_{ru})+3\frac{l_{(r+1)(r+2)}}{\lambda}\right\}$$

$$R_{rl}=K_{(r-1)(r+1)}\left\{2(\tan\theta_{rl}-\tan\theta_{ru})+3\frac{l_{(r+1)(r+2)}}{\lambda}\right\}$$

$$R_{ru}=K_{r(r+2)}\left\{2(\tan\theta_{rl}-\tan\theta_{ru})+3\frac{l_{(r+1)(r+2)}}{\lambda}\right\}$$

$$L_{rl}=K_{(r-1)(r+1)}\left\{(\tan\theta_{rl}-\tan\theta_{ru})+2\frac{l_{(r+1)(r+2)}}{\lambda}\right\}$$

$$L_{ru}=K_{r(r+2)}\left\{(\tan\theta_{rl}-\tan\theta_{ru})+2\frac{l_{(r+1)(r+2)}}{\lambda}\right\}$$

$$T_r=-\{l_{(r+1)(r+2)}\tan\theta_{rl}+\lambda(\tan\theta_{rl}-\tan\theta_{ru})(\tan\theta_{2l}+\tan\theta_{4l}+\cdots\cdots+\tan\theta_{rl})\}$$

$$S_r=l_{(r+1)(r+2)}+\frac{r}{2}\lambda(\tan\theta_{rl}-\tan\theta_{ru})$$

$$\gamma_r=\left\{l_{(r+1)(r+2)}+\frac{r}{2}\lambda(\tan\theta_{rl}-\tan\theta_{ru})\right\}P_2+\left\{l_{(r+1)(r+2)}+\left(\frac{r}{2}-1\right)\lambda(\tan\theta_{rl}-\tan\theta_{ru})\right\}$$
$$\times(P_3+P_4)+\cdots\cdots+\{l_{(r+1)(r+2)}+\lambda(\tan\theta_{rl}-\tan\theta_{ru})\}(P_{r-1}+P_r)$$

(C) 格間釣合方程式

(IV) 式の N に 3. で求めた N の値を入れて整理すれば一般に次式を得る。

$$i_r[M_1]+a_{rl}\varphi_{r-3}+a_{ru}\varphi_{r-2}+b_{rl}\varphi_{r-1}+b_{ru}\varphi_r+c_{rl}\varphi_{r+1}+c_{ru}\varphi_{r+2}+d_{rl}\varphi_{r+3}+d_{ru}\varphi_{r+4}$$
$$+e_{rl}\mu_{(r-2)l}+e_{ru}\mu_{(r-2)u}+f_{rl}\mu_{rl}+f_{ru}\mu_{ru}+g_{rl}\mu_{(r+2)l}+g_{ru}\mu_{(r+2)u}+h_r[H]+k_r[A]=\varepsilon_r+\zeta_r$$

この式を格間 1―3($r=2$), 3―5($r=4$), 5―7($r=6$) に適用すれば夫々 (21), (23), (25) 式を得る。 橋の右半分に対しても同様に (22), (24), (26) 式を得る。

$$i_r=-\left\{\frac{1}{l_{(r+1)(r+2)}}\left(\frac{\tan\theta_{rl}}{A_{(r-1)(r+1)}\cos\theta_{rl}}+\frac{\tan\theta_{ru}}{A_{r(r+2)}\cos\theta_{ru}}\right)-\frac{1}{\lambda}\left(\frac{1}{A_{(r-1)r}}\tan\theta_{(r-2)u}\right.\right.$$
$$\left.\left.-\frac{1}{A_{(r+1)(r+2)}}\tan\theta_{ru}\right)+\frac{1}{\lambda}\left(\frac{l_{(r-1)r}}{l_{(r+1)(r+2)}A_{(r-1)r}}\tan\theta_{ru}-\frac{l_{(r+1)(r+2)}}{l_{(r+3)(r+4)}A_{(r+1)(r+2)}}\tan\theta_{(r+2)u}\right)\right\}$$

$$a_{rl}=-\frac{K_{(r-3)(r-1)}}{\lambda A_{(r-1)r}}\tan\theta_{(r-2)u}$$

$$a_{ru}=-\frac{K_{(r-2)r}}{\lambda A_{(r-1)r}}\left(\tan\theta_{(r-2)u}-3\frac{l_{(r-1)r}}{\lambda}\right)$$

$$b_{rl}=\frac{K_{(r-1)(r+1)}}{l_{(r+1)(r+2)}}\left(\frac{\tan\theta_{rl}}{A_{(r-1)(r+1)}\cos\theta_{rl}}+\frac{\tan\theta_{ru}}{A_{r(r+2)}\cos\theta_{ru}}\right)+3\frac{K_{(r-1)(r+1)}}{\lambda A_{(r-1)(r+1)}}\sin\theta_{rl}\tan\theta_{rl}$$
$$-2\frac{K_{(r-3)(r-1)}}{\lambda A_{(r-1)(r+1)}}\tan\theta_{(r-2)u}+\frac{K_{(r-1)(r+1)}}{\lambda}\left(\frac{1}{A_{(r+1)(r+2)}}+\frac{l_{(r-1)r}}{l_{(r+1)(r+2)}A_{(r-1)r}}\right)\tan\theta_{ru}$$

$$b_{ru}=\frac{K_{r(r+2)}}{l_{(r+1)(r+2)}}\left(\frac{\tan\theta_{rl}}{A_{(r-1)(r+1)}\cos\theta_{rl}}+\frac{\tan\theta_{ru}}{A_{r(r+2)}\cos\theta_{ru}}\right)-3\frac{K_{r(r+2)}}{\lambda A_{r(r+2)}}\sin\theta_{ru}\tan\theta_{ru}$$
$$-2\frac{K_{(r-2)r}}{\lambda A_{(r-1)r}}\tan\theta_{(r-2)u}+\frac{K_{r(r+2)}}{\lambda}\left(\frac{1}{A_{(r+1)(r+2)}}+\frac{l_{(r-1)r}}{l_{(r+1)(r+2)}A_{(r-1)r}}\right)\tan\theta_{ru}$$
$$+3\frac{K_{(r-2)r}l_{(r-1)r}}{\lambda^2A_{(r-1)r}}-3\frac{K_{r(r+2)}}{\lambda^2}\left(\frac{l_{(r-1)r}}{A_{(r-1)r}}+\frac{l_{(r+1)(r+2)}}{A_{(r+1)(r+2)}}\right)$$

$$c_{rl}=2\frac{K_{(r-1)(r+1)}}{l_{(r+1)(r+2)}}\left(\frac{\tan\theta_{rl}}{A_{(r-1)(r+1)}\cos\theta_{rl}}+\frac{\tan\theta_{ru}}{A_{r(r+2)}\cos\theta_{ru}}\right)+3\frac{K_{(r-1)(r+1)}}{\lambda A_{(r-1)(r+1)}}\sin\theta_{rl}\tan\theta_{rl}$$

$$+2\frac{K_{(r-1)(r+1)}}{\lambda}\left(\frac{1}{A_{(r+1)(r+2)}}+\frac{l_{(r-1)r}}{l_{(r+1)(r+2)}A_{(r-1)r}}\right)\tan\theta_{ru}-\frac{K_{(r+1)(r+3)}l_{(r+1)(r+2)}}{l_{(r+3)(r+4)}\lambda A_{(r+1)(r+2)}}\tan\theta_{(r+2)u}$$

$$c_{ru}=2\frac{K_{r(r+2)}}{l_{(r+1)(r+2)}}\left(\frac{\tan\theta_{rl}}{A_{(r-1)(r+1)}\cos\theta_{rl}}+\frac{\tan\theta_{ru}}{A_{r(r+2)}\cos\theta_{ru}}\right)-3\frac{K_{r(r+2)}}{\lambda A_{r(r+2)}}\sin\theta_{ru}\tan\theta_{ru}$$

$$+2\frac{K_{r(r+2)}}{\lambda}\left(\frac{1}{A_{(r+1)(r+2)}}+\frac{l_{(r-1)r}}{l_{(r+1)(r+2)}A_{(r-1)r}}\right)\tan\theta_{ru}-\frac{K_{(r+2)(r+4)}l_{(r+1)(r+2)}}{l_{(r+3)(r+4)}\lambda A_{(r+1)(r+2)}}\tan\theta_{(r+2)u}$$

$$-3\frac{K_{r(r+2)}}{\lambda}\left(\frac{l_{(r-1)r}}{A_{(r-1)r}}+\frac{l_{(r+1)(r+2)}}{A_{(r+1)(r+2)}}\right)+3\frac{K_{(r+2)(r+4)}l_{(r+1)(r+2)}}{\lambda^2 A_{(r+1)(r+2)}}$$

$$d_{rl}=-2\frac{K_{(r+1)(r+3)}l_{(r+1)(r+2)}}{l_{(r+3)(r+4)}\lambda A_{(r+1)(r+2)}}\tan\theta_{(r+2)u}$$

$$d_{ru}=\frac{K_{(r+2)(r+4)}}{A_{(r+1)(r+2)}}\left(-\frac{2}{\lambda}\,\frac{l_{(r+1)(r+2)}}{l_{(r+3)(r+4)}}\tan\theta_{(r+2)u}+3\frac{l_{(r+1)(r+2)}}{\lambda^2}\right)$$

$$e_{rl}=-\frac{K_{(r-3)(r-1)}}{\lambda A_{(r-1)r}}\tan\theta_{(r-2)u}$$

$$e_{ru}=\frac{K_{(r-2)r}}{A_{(r-1)r}}\left(-\frac{1}{\lambda}\tan\theta_{(r-2)u}+2\frac{l_{(r-1)r}}{\lambda^2}\right)$$

$$f_{rl}=\frac{1}{6}+\frac{K_{(r-1)(r+1)}}{l_{(r+1)(r+2)}}\left(\frac{\tan\theta_{rl}}{A_{(r-1)(r+1)}\cos\theta_{rl}}+\frac{\tan\theta_{ru}}{A_{r(r+2)}\cos\theta_{ru}}\right)+2\frac{K_{(r-1)(r+1)}}{\lambda A_{(r-1)(r+1)}}\sin\theta_{rl}\tan\theta_{rl}$$

$$+\frac{K_{(r-1)(r+1)}}{\lambda}\left(\frac{1}{A_{(r+1)(r+2)}}+\frac{l_{(r-1)r}}{l_{(r+1)(r+2)}A_{(r-1)r}}\right)\tan\theta_{ru}$$

$$f_{ru}=-\frac{1}{6}+\frac{K_{r(r+2)}}{l_{(r+1)(r+2)}}\left(\frac{\tan\theta_{rl}}{A_{(r-1)(r+1)}\cos\theta_{rl}}+\frac{\tan\theta_{ru}}{A_{r(r+2)}\cos\theta_{ru}}\right)-2\frac{K_{r(r+2)}}{\lambda A_{r(r+2)}}\sin\theta_{ru}\tan\theta_{ru}$$

$$+\frac{K_{r(r+2)}}{\lambda}\left(\frac{1}{A_{(r+1)(r+2)}}+\frac{l_{(r-1)r}}{l_{(r+1)(r+2)}A_{(r-1)r}}\right)\tan\theta_{ru}-2\frac{K_{r(r+2)}}{\lambda^2}\left(\frac{l_{(r-1)r}}{A_{(r-1)r}}+\frac{l_{(r+1)(r+2)}}{A_{(r+1)(r+2)}}\right)$$

$$g_{rl}=-\frac{K_{(r+1)(r+3)}l_{(r+1)(r+2)}}{l_{(r+3)(r+4)}\lambda A_{(r+1)(r+2)}}\tan\theta_{(r+2)u}$$

$$g_{ru}=\frac{K_{(r+2)(r+4)}}{A_{(r+1)(r+2)}}\left(-\frac{1}{\lambda}\,\frac{l_{(r+1)(r+2)}}{l_{(r+3)(r+4)}}\tan\theta_{(r+2)u}+2\frac{l_{(r+1)(r+2)}}{\lambda^2}\right)$$

$$h_r=-\frac{\tan\theta_{rl}}{A_{(r-1)(r+1)}\cos\theta_{rl}}-\frac{\lambda}{l_{(r+1)(r+2)}}\left(\frac{\tan\theta_{rl}}{A_{(r-1)(r+1)}\cos\theta_{rl}}+\frac{\tan\theta_{ru}}{A_{r(r+2)}\cos\theta_{ru}}\right)$$

$$\times(\tan\theta_{2l}+\tan\theta_{4l}+\cdots\cdots+\tan\theta_{rl})+\frac{\tan\theta_{(r-2)u}}{A_{(r-1)r}}(\tan\theta_{2l}+\tan\theta_{4l}+\cdots\cdots+\tan\theta_{(r-2)l})$$

$$-\left(\frac{1}{A_{(r+1)(r+2)}}+\frac{l_{(r-1)r}}{l_{(r+1)(r+2)}A_{(r-1)r}}\right)\tan\theta_{ru}(\tan\theta_{2l}+\tan\theta_{4l}+\cdots\cdots+\tan\theta_{rl})$$

$$+\frac{l_{(r+1)(r+2)}}{l_{(r+3)(r+4)}A_{(r+1)(r+2)}}\tan\theta_{(r+2)u}(\tan\theta_{2l}+\tan\theta_{4l}+\cdots\cdots+\tan\theta_{(r+2)l})$$

$$k_r=\frac{\frac{r}{2}\lambda}{l_{(r+1)(r+2)}}\left(\frac{\tan\theta_{rl}}{A_{(r-1)(r+1)}\cos\theta_{rl}}+\frac{\tan\theta_{ru}}{A_{r(r+2)}\cos\theta_{ru}}\right)-\left(\frac{r}{2}-1\right)\frac{\tan\theta_{(r-2)u}}{A_{(r-1)r}}$$

$$+\frac{r}{2}\left(\frac{1}{A_{(r+1)(r+2)}}+\frac{l_{(r-1)r}}{l_{(r+1)(r+2)}A_{(r-1)r}}\right)\tan\theta_{ru}-\left(\frac{r}{2}+1\right)\frac{l_{(r+1)(r+2)}\tan\theta_{(r+2)u}}{l_{(r+3)(r+4)}A_{(r+1)(r+2)}}$$

$$\varepsilon_r=\left\{\frac{\frac{r}{2}\lambda}{l_{(r+1)(r+2)}}\left(\frac{\tan\theta_{rl}}{A_{(r-1)(r+1)}\cos\theta_{rl}}+\frac{\tan\theta_{ru}}{A_{r(r+2)}\cos\theta_{ru}}\right)-\left(\frac{r}{2}-1\right)\frac{\tan\theta_{(r-2)u}}{A_{(r-1)r}}\right.$$

$$\left.+\frac{r}{2}\left(\frac{1}{A_{(r+1)(r+2)}}+\frac{l_{(r-1)r}}{l_{(r+1)(r+2)}A_{(r-1)r}}\right)\tan\theta_{ru}-\left(\frac{r}{2}+1\right)\frac{l_{(r+1)(r+2)}\tan\theta_{(r+2)u}}{l_{(r+3)(r+4)}A_{(r+1)(r+2)}}\right\}P_2$$

$$+\left\{\frac{\left(\frac{r}{2}-1\right)\lambda}{l_{(r+1)(r+2)}}\left(\frac{\tan\theta_{rl}}{A_{(r-1)(r+1)}\cos\theta_{rl}}+\frac{\tan\theta_{ru}}{A_{r(r+2)}\cos\theta_{ru}}\right)-\left(\frac{r}{2}-2\right)\frac{\tan\theta_{(r-2)u}}{A_{(r-1)r}}\right.$$

$$\left.+\left(\frac{r}{2}-1\right)\left(\frac{1}{A_{(r+1)(r+2)}}+\frac{l_{(r-1)r}}{l_{(r+1)(r+2)}A_{(r-1)r}}\right)\tan\theta_{ru}-\frac{r}{2}\,\frac{l_{(r+1)(r+2)}\tan\theta_{(r+2)u}}{l_{(r+3)(r+4)}A_{(r+1)(r+2)}}\right\}(P_3+P_4)$$

$$+\cdots\cdots+\Bigl\{\frac{2\lambda}{l_{(r+1)(r+2)}}\Bigl(\frac{\tan\theta_{rl}}{A_{(r-1)(r+1)}\cos\theta_{rl}}+\frac{\tan\theta_{ru}}{A_{r(r+2)}\cos\theta_{ru}}\Bigr)-\frac{\tan\theta_{(r-2)u}}{A_{(r-1)r}}+2\Bigl(\frac{1}{A_{(r+1)(r+2)}}$$

$$+\frac{l_{(r-1)r}}{l_{(r+1)(r+2)}A_{(r-1)r}}\Bigr)\tan\theta_{ru}-3\frac{l_{(r+1)(r+2)}\tan\theta_{(r+2)u}}{l_{(r+3)(r+4)}A_{(r+1)(r+2)}}\Bigr\}(P_{r-3}+P_{r-2})$$

$$+\Bigl\{\frac{\lambda}{l_{(r+1)(r+2)}}\Bigl(\frac{\tan\theta_{rl}}{A_{(r-1)(r+1)}\cos\theta_{rl}}+\frac{\tan\theta_{ru}}{A_{r(r+2)}\cos\theta_{ru}}\Bigr)+\Bigl(\frac{1}{A_{(r+1)(r+2)}}$$

$$+\frac{l_{(r-1)r}}{l_{(r+1)(r+2)}A_{(r-1)r}}\Bigr)\tan\theta_{ru}-2\frac{l_{(r+1)(r+2)}\tan\theta_{(r+2)u}}{l_{(r+3)(r+4)}A_{(r+1)(r+2)}}\Bigr\}P_{r-1}+\Bigl\{\frac{\lambda}{l_{(r+1)(r+2)}}$$

$$\times\Bigl(\frac{\tan\theta_{rl}}{A_{(r-1)(r+1)}\cos\theta_{rl}}+\frac{\tan\theta_{ru}}{A_{r(r+2)}\cos\theta_{ru}}\Bigr)+\Bigl(\frac{1}{A_{(r+1)(r+2)}}+\frac{l_{(r-1)r}}{l_{(r+1)(r+2)}A_{(r-1)r}}\Bigr)\tan\theta_{ru}$$

$$-2\frac{l_{(r+1)(r+2)}\tan\theta_{(r+2)u}}{l_{(r+3)(r+4)}A_{(r+1)(r+2)}}-\frac{l_{(r-1)r}}{\lambda A_{(r-1)r}}\Bigr\}P_r-\frac{l_{(r+1)(r+2)}\tan\theta_{(r+2)u}}{l_{(r+3)(r+4)}A_{(r+1)(r+2)}}P_{r+1}$$

$$+\Bigl\{-\frac{l_{(r+1)(r+2)}\tan\theta_{(r+2)u}}{l_{(r+3)(r+4)}A_{(r+1)(r+2)}}+\frac{l_{(r+1)(r+2)}}{\lambda A_{(r+1)(r+2)}}\Bigr\}P_{r+2}$$

(D)　垂直材釣合方程式

垂直材の上端の剪断力の釣合を考えて

$$\frac{M_{12}+M_{21}}{l_{12}}+\frac{M_{1'2'}+M_{2'1'}}{l_{1'2'}}+\frac{M_{34}+M_{43}}{l_{34}}+\frac{M_{3'4'}+M_{4'3'}}{l_{3'4'}}+\frac{M_{56}+M_{65}}{l_{56}}+\frac{M_{5'6'}+M_{6'5'}}{l_{5'6'}}$$

$$+\frac{M_{78}+M_{87}}{l_{78}}=-W_2-W_2'-W_4-W_4'-W_6-W_6'-W_8$$

この式の M を φ, μ で表わして整理すれば (27) 式を得る。

$$w_r=4\lambda\Bigl\{\frac{1}{l_{34}}\frac{K_{12}}{l_{12}^2}\Bigl(\frac{1}{A_{13}\cos\theta_{2l}}+\frac{1}{A_{24}\cos\theta_{2u}}\Bigr)+\frac{1}{l_{56}}\Bigl(\frac{K_{12}}{l_{12}^2}+\frac{K_{34}}{l_{34}^2}\Bigr)\Bigl(\frac{1}{A_{35}\cos\theta_{4l}}+\frac{1}{A_{46}\cos\theta_{4u}}\Bigr)+\cdots\cdots$$

$$+\frac{1}{l_{(n+1)(n+2)}}\Bigl(\frac{K_{12}}{l_{12}^2}+\frac{K_{34}}{l_{34}^2}+\cdots\cdots+\frac{K_{(n-1)n}}{l_{(n-1)n}^2}\Bigr)\Bigl(\frac{1}{A_{(n-1)(n+1)}\cos\theta_{nl}}+\frac{1}{A_{n(n+2)}\cos\theta_{nu}}\Bigr)\Bigr\}$$

$$m_{rl}=\frac{K_{(r-1)r}}{l_{(r-1)r}}-8\frac{K_{(r-3)(r-1)}}{l_{(r-1)r}}\lambda\Bigl(\frac{K_{12}}{l_{12}^2}+\frac{K_{34}}{l_{34}^2}+\cdots\cdots+\frac{K_{(r-3)(r-2)}}{l_{(r-3)(r-2)}^2}\Bigr)\Bigl(\frac{1}{A_{(r-3)(r-1)}\cos\theta_{(r-2)l}}$$

$$+\frac{1}{A_{(r-2)r}\cos\theta_{(r-2)u}}\Bigr)-4\frac{K_{(r-1)(r+1)}}{l_{(r+1)(r+2)}}\lambda\Bigl(\frac{K_{12}}{l_{12}^2}+\frac{K_{34}}{l_{34}^2}+\cdots\cdots+\frac{K_{(r-1)r}}{l_{(r-1)r}^2}\Bigr)\Bigl(\frac{1}{A_{(r-1)(r+1)}\cos\theta_{rl}}$$

$$+\frac{1}{A_{r(r+2)}\cos\theta_{ru}}\Bigr)-12\frac{K_{(r-3)(r-1)}}{A_{(r-3)(r-1)}}\Bigl(\frac{K_{12}}{l_{12}^2}+\frac{K_{34}}{l_{34}^2}+\cdots\cdots+\frac{K_{(r-3)(r-2)}}{l_{(r-3)(r-2)}^2}\Bigr)\sin\theta_{(r-2)l}$$

$$-12\frac{K_{(r-1)(r+1)}}{A_{(r-1)(r+1)}}\Bigl(\frac{K_{12}}{l_{12}^2}+\frac{K_{34}}{l_{34}^2}+\cdots\cdots+\frac{K_{(r-1)r}}{l_{(r-1)r}^2}\Bigr)\sin\theta_{rl}$$

$$m_{ru}=\frac{K_{(r-1)r}}{l_{(r-1)r}}-8\frac{K_{(r-2)r}}{l_{(r-1)r}}\lambda\Bigl(\frac{K_{12}}{l_{12}^2}+\frac{K_{34}}{l_{34}^2}+\cdots\cdots+\frac{K_{(r-3)(r-2)}}{l_{(r-3)(r-2)}^2}\Bigr)\Bigl(\frac{1}{A_{(r-3)(r-1)}\cos\theta_{(r-2)l}}$$

$$+\frac{1}{A_{(r-2)r}\cos\theta_{(r-2)u}}\Bigr)-4\frac{K_{r(r+2)}}{l_{(r+1)(r+2)}}\lambda\Bigl(\frac{K_{12}}{l_{12}^2}+\frac{K_{34}}{l_{34}^2}+\cdots\cdots+\frac{K_{(r-1)r}}{l_{(r-1)r}^2}\Bigr)\Bigl(\frac{1}{A_{(r-1)(r+1)}\cos\theta_{rl}}$$

$$+\frac{1}{A_{r(r+2)}\cos\theta_{ru}}\Bigr)+12\frac{K_{(r-2)r}}{A_{(r-2)r}}\Bigl(\frac{K_{12}}{l_{12}^2}+\frac{K_{34}}{l_{34}^2}+\cdots\cdots+\frac{K_{(r-3)(r-2)}}{l_{(r-3)(r-2)}^2}\Bigr)\sin\theta_{(r-2)u}$$

$$+12\frac{K_{r(r+2)}}{A_{r(r+2)}}\Bigl(\frac{K_{12}}{l_{12}^2}+\frac{K_{34}}{l_{34}^2}+\cdots\cdots+\frac{K_{(r-1)r}}{l_{(r-1)r}^2}\Bigr)\sin\theta_{ru}$$

$$m^{\circ}_{(n+2)l}=m_{(n+2)l}+m_{(n+2)'l}-\frac{K_{(n+1)'(n+2)'}}{l_{(n+1)'(n+2)'}}$$

$$m^{\circ}_{(n+2)u}=m_{(n+2)u}+m_{(n+2)'u}-\frac{K_{(n+1)'(n+2)'}}{l_{(n+1)'(n+2)'}}$$

$$n_{rl}=\frac{2}{3}\lambda\Bigl(\frac{K_{12}}{l_{12}^2}+\frac{K_{34}}{l_{34}^2}+\cdots\cdots+\frac{K_{(r-1)r}}{l_{(r-1)r}^2}\Bigr)\tan\theta_{rl}-4\frac{K_{(r-1)(r+1)}}{l_{(r+1)(r+2)}}\lambda\Bigl(\frac{K_{12}}{l_{12}^2}+\frac{K_{34}}{l_{34}^2}+\cdots\cdots$$

$$+\frac{K_{(r-1)r}}{l_{(r-1)r}^2}\Bigr)\Bigl(\frac{1}{A_{(r-1)(r+1)}\cos\theta_{rl}}+\frac{1}{A_{r(r+2)}\cos\theta_{ru}}\Bigr)-8\frac{K_{(r-1)(r+1)}}{A_{(r-1)(r+1)}}\Bigl(\frac{K_{12}}{l_{12}^2}+\frac{K_{34}}{l_{34}^2}$$

$$+\cdots\cdots+\frac{K_{(r-1)r}}{l_{(r-1)r}^2}\Bigr)\sin\theta_{rl}$$

$$n_{ru}=-\frac{2}{3}\lambda\Bigl(\frac{K_{12}}{l_{12}^2}+\frac{K_{34}}{l_{34}^2}+\cdots\cdots+\frac{K_{(r-1)r}}{l_{(r-1)r}^2}\Bigr)\tan\theta_{ru}-4\frac{K_{r(r+2)}}{l_{(r+1)(r+2)}}\lambda\Bigl(\frac{K_{12}}{l_{12}^2}+\frac{K_{34}}{l_{34}^2}+\cdots\cdots+\frac{K_{(r-1)r}}{l_{(r-1)r}^2}\Bigr)$$

$$\times\left(\frac{1}{A_{(r-1)(r+1)}\cos\theta_{rl}}+\frac{1}{A_{r(n+2)}\cos\theta_{ru}}\right)+8\frac{K_{r(r+2)}}{A_{r(r+2)}}\left(\frac{K_{12}}{l_{12}^{2}}+\frac{K_{34}}{l_{34}^{2}}+\cdots\cdots+\frac{K_{(r-1)r}}{l_{(r-1)r}^{2}}\right)\sin\theta_{ru}$$

$$s=\frac{2}{3}\left(\frac{K_{12}}{l_{12}^{2}}+\frac{K_{1'2'}}{l_{1'2'}^{2}}+\frac{K_{34}}{l_{34}^{2}}+\frac{K_{3'4'}}{l_{3'4'}^{2}}+\cdots\cdots+\frac{K_{(n-1)n}}{l_{(n-1)n}^{2}}+\frac{K_{(n-1)'n'}}{l_{(n-1)'n'}^{2}}+\frac{K_{(n+1)(n+2)}}{l_{(n+1)(n+2)}^{2}}\right)l_{(n+1)(n+2)}$$

$$u=4\lambda\left\{\frac{K_{12}}{l_{12}^{2}}\ \frac{1}{A_{13}\cos\theta_{2l}}+\left(\frac{K_{12}}{l_{12}^{2}}+\frac{K_{34}}{l_{34}^{2}}\right)\frac{1}{A_{35}\cos\theta_{4l}}+\cdots\cdots+\left(\frac{K_{12}}{l_{12}^{2}}+\frac{K_{34}}{l_{34}^{2}}+\cdots\cdots+\frac{K_{(n-1)n}}{l_{(n-1)n}^{2}}\right)\right.$$

$$\times\frac{1}{A_{(n-1)(n+1)}\cos\theta_{nl}}+\frac{\lambda}{l_{34}}\ \frac{K_{12}}{l_{12}^{2}}\left(\frac{1}{A_{13}\cos\theta_{2l}}+\frac{1}{A_{24}\cos\theta_{2u}}\right)\tan\theta_{2l}+\frac{\lambda}{l_{56}}\left(\frac{K_{12}}{l_{12}^{2}}+\frac{K_{34}}{l_{34}^{2}}\right)$$

$$\times\left(\frac{1}{A_{35}\cos\theta_{4l}}+\frac{1}{A_{46}\cos\theta_{4u}}\right)(\tan\theta_{2l}+\tan\theta_{4l})+\cdots\cdots+\frac{\lambda}{l_{(n+1)(n+2)}}\left(\frac{K_{12}}{l_{12}^{2}}+\frac{K_{34}}{l_{34}^{2}}+\cdots\cdots\right.$$

$$\left.+\frac{K_{(n-1)n}}{l_{(n-1)n}^{2}}\right)\left(\frac{1}{A_{(n-1)(n+1)}\cos\theta_{nl}}+\frac{1}{A_{n(n+2)}\cos\theta_{nu}}\right)(\tan\theta_{2l}+\tan\theta_{4l}+\cdots\cdots$$

$$\left.+\tan\theta_{nl})\right\}-4\lambda\left\{\frac{K_{1'2'}}{l_{1'2'}^{2}}\ \frac{1}{A_{1'3'}\cos\theta_{2'l}}+\cdots\cdots+\left(\frac{K_{1'2'}}{l_{1'2'}^{2}}+\frac{K_{3'4'}}{l_{3'4'}^{2}}+\cdots\cdots+\frac{K_{(n-1)'n'}}{l_{(n-1)'n'}^{2}}\right)\right.$$

$$\times\frac{1}{A_{(n-1)'(n+1)'}\cos\theta_{n'l}}+\frac{\lambda}{l_{3'4'}}\ \frac{K_{1'2'}}{l_{1'2'}^{2}}\left(\frac{1}{A_{1'3'}\cos\theta_{2'l}}+\frac{1}{A_{2'4'}\cos\theta_{2'u}}\right)\tan\theta_{2'l}+\cdots\cdots$$

$$+\frac{\lambda}{l_{(n+1)'(n+2)'}}\left(\frac{K_{1'2'}}{l_{1'2'}^{2}}+\frac{K_{3'4'}}{l_{3'4'}^{2}}+\cdots\cdots+\frac{K_{(n-1)'n'}}{l_{(n-1)'n'}^{2}}\right)\left(\frac{1}{A_{(n-1)'(n+1)'}\cos\theta_{n'l}}\right.$$

$$\left.\left.+\frac{1}{A_{n'(n+2)'}\cos\theta_{n'u}}\right)(\tan\theta_{2'l}+\tan\theta_{4'l}+\cdots\cdots+\tan\theta_{n'l})\right\}$$

$$v_r=-4\lambda^2\left\{\frac{1}{l_{34}}\ \frac{K_{12}}{l_{12}^{2}}\left(\frac{1}{A_{13}\cos\theta_{2l}}+\frac{1}{A_{24}\cos\theta_{2u}}\right)+\frac{2}{l_{56}}\left(\frac{K_{12}}{l_{12}^{2}}+\frac{K_{34}}{l_{34}^{2}}\right)\left(\frac{1}{A_{35}\cos\theta_{4l}}+\frac{1}{A_{46}\cos\theta_{4u}}\right)\right.$$

$$\left.+\cdots\cdots+\frac{\frac{n}{2}}{l_{(n+1)(n+2)}}\left(\frac{K_{12}}{l_{12}^{2}}+\frac{K_{34}}{l_{34}^{2}}+\cdots\cdots+\frac{K_{(n-1)n}}{l_{(n-1)n}^{2}}\right)\left(\frac{1}{A_{(n-1)(n+1)}\cos\theta_{nl}}+\frac{1}{A_{n(n+2)}\cos\theta_{nu}}\right)\right\}$$

$$\eta=-4\lambda^2\left\{\frac{1}{l_{34}}\ \frac{K_{12}}{l_{12}^{2}}\left(\frac{1}{A_{13}\cos\theta_{2l}}+\frac{1}{A_{24}\cos\theta_{2u}}\right)+\frac{2}{l_{56}}\left(\frac{K_{12}}{l_{12}^{2}}+\frac{K_{34}}{l_{34}^{2}}\right)\left(\frac{1}{A_{35}\cos\theta_{4l}}+\frac{1}{A_{46}\cos\theta_{4u}}\right)\right.$$

$$+\cdots\cdots+\frac{\frac{n}{2}}{l_{(n+1)(n+2)}}\left(\frac{K_{12}}{l_{12}^{2}}+\frac{K_{34}}{l_{34}^{2}}+\cdots\cdots+\frac{K_{(n-1)n}}{l_{(n-1)n}^{2}}\right)\left(\frac{1}{A_{(n-1)(n+1)}\cos\theta_{nl}}\right.$$

$$\left.\left.+\frac{1}{A_{n(n+2)}\cos\theta_{nu}}\right)\right\}P_2-4\lambda^2\left\{\frac{1}{l_{56}}\left(\frac{K_{12}}{l_{12}^{2}}+\frac{K_{34}}{l_{34}^{2}}\right)\left(\frac{1}{A_{35}\cos\theta_{4l}}+\frac{1}{A_{46}\cos\theta_{4u}}\right)\right.$$

$$+\frac{2}{l_{78}}\left(\frac{K_{12}}{l_{12}^{2}}+\frac{K_{34}}{l_{34}^{2}}+\frac{K_{56}}{l_{56}^{2}}\right)\left(\frac{1}{A_{57}\cos\theta_{6l}}+\frac{1}{A_{68}\cos\theta_{6u}}\right)+\cdots\cdots+\frac{\frac{n}{2}-1}{l_{(n+1)(n+2)}}$$

$$\left.\times\left(\frac{K_{12}}{l_{12}^{2}}+\frac{K_{34}}{l_{34}^{2}}+\cdots\cdots+\frac{K_{(n-1)n}}{l_{(n-1)n}^{2}}\right)\left(\frac{1}{A_{(n-1)(n+1)}\cos\theta_{nl}}+\frac{1}{A_{n(n+2)}\cos\theta_{nu}}\right)\right\}(P_3+P_4)$$

$$-\cdots\cdots-4\lambda^2\left\{\frac{1}{l_{(n+1)(n+2)}}\left(\frac{K_{12}}{l_{12}^{2}}+\frac{K_{34}}{l_{34}^{2}}+\cdots\cdots+\frac{K_{(n-1)n}}{l_{(n-1)n}^{2}}\right)\right.$$

$$\left.\times\left(\frac{1}{A_{(n-1)(n+1)}\cos\theta_{nl}}+\frac{1}{A_{n(n+2)}\cos\theta_{nu}}\right)\right\}(P_{n-1}+P_n)+4\lambda^2\left\{\frac{1}{l_{3'4'}}\ \frac{K_{1'2'}}{l_{1'2'}^{2}}\left(\frac{1}{A_{1'3'}\cos\theta_{2'l}}\right.\right.$$

$$\left.+\frac{1}{A_{2'4'}\cos\theta_{2'u}}\right)+\frac{2}{l_{5'6'}}\left(\frac{K_{1'2'}}{l_{1'2'}^{2}}+\frac{K_{3'4'}}{l_{3'4'}^{2}}\right)\left(\frac{1}{A_{3'5'}\cos\theta_{4'l}}+\frac{1}{A_{4'6'}\cos\theta_{4'u}}\right)+\cdots\cdots$$

$$+\frac{\frac{n}{2}}{l_{(n+1)'(n+2)'}}\left(\frac{K_{1'2'}}{l_{1'2'}^{2}}+\frac{K_{3'4'}}{l_{3'4'}^{2}}+\cdots\cdots+\frac{K_{(n-1)'n'}}{l_{(n-1)'n'}^{2}}\right)\left(\frac{1}{A_{(n-1)'(n+1)'}\cos\theta_{n'l}}\right.$$

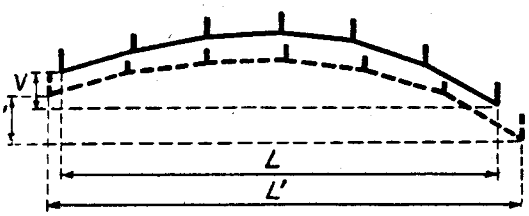
$$\left.\left.+\frac{1}{A_{n'(n+2)'}\cos\theta_{n'u}}\right)\right\}P_2'+\cdots\cdots+4\lambda^2\left\{\frac{1}{l_{(n+1)'(n+2)'}}\left(\frac{K_{1'2'}}{l_{1'2'}^{2}}+\frac{K_{3'4'}}{l_{3'4'}^{2}}+\cdots\cdots\right.\right.$$

$$\left.\left.+\frac{K_{(n-1)'n'}}{l_{(n-1)'n'}^{2}}\right)\left(\frac{1}{A_{(n-1)'(n+1)'}\cos\theta_{n'l}}+\frac{1}{A_{n'(n+2)'}\cos\theta_{n'u}}\right)\right\}(P_{(n-1)'}+P_{n'})$$

[illegible] 支間釣合方程式

[illegible]が[illegible]—5のように実線の位置から変形後点線の位置に移つたとし，支点の相対移動を次のように表わ

図—5



水平方向 $\Delta=L'-L$, 垂直方向 $\Omega=V'-V$.

(a) 水平方向:

$$L=\Sigma(l_{(r-1)(r+1)}\cos\theta_{rl}+l_{(r-1)'(r+1)'}\cos\theta_{r'l})$$

$$L'=\Sigma\{(l_{(r-1)(r+1)}+\Delta l_{(r-1)(r+1)})\cos(\theta_{rl}-\psi_{rl})+(l_{(r-1)'(r+1)'}+\Delta l_{(r-1)'(r+1)'})\cos(\theta_{r'l}+\psi_{r'l})\}$$

$$r=2,4,6,\cdots\cdots,n$$

$\psi_{rl},\psi_{r'l}$ は極めて小さいから $\cos\psi_{rl}=1$, $\sin\psi_{rl}=\psi_{rl}$, $\cos\psi_{r'l}=1$, $\sin\psi_{r'l}=\psi_{r'l}$ とおき，更に $\Delta l_{(r-1)(r+1)}$, ψ_{rl}, $\Delta l_{(r-1)'(r+1)'}\psi_{r'l}$ を含む項は2次の微小量であるから省略すれば $L'-L$ は次のようになる。

$$L'-L=\Sigma(l_{(r-1)(r+1)}\psi_{rl}\sin\theta_{rl}+\Delta l_{(r-1)(r+1)}\cos\theta_{rl}-l_{(r-1)'(r+1)'}\psi_{r'l}\sin\theta_{r'l}+\Delta l_{(r-1)'(r+1)'}\cos\theta_{r'l})=\Delta$$

この式に

$$l_{(r-1)(r+1)}=\frac{\lambda}{\cos\theta_{rl}},\quad l_{(r-1)'(r+1)'}=\frac{\lambda}{\cos\theta_{r'l}},\quad \Delta l_{(r-1)(r+1)}=\frac{N_{(r-1)(r+1)}}{EA_{(r-1)(r+1)}}\frac{\lambda}{\cos\theta_{rl}}+\varepsilon t\frac{\lambda}{\cos\theta_{rl}},$$

$$\Delta l_{(r-1)'(r+1)'}=\frac{N_{(r-1)'(r+1)'}}{EA_{(r-1)'(r+1)'}}\frac{\lambda}{\cos\theta_{r'l}}+\varepsilon t\frac{\lambda}{\cos\theta_{r'l}}$$

を入れ，両辺に $-6E\dfrac{1}{\lambda}$ を乗ずれば

$$\Sigma\left\{\tan\theta_{rl}\mu_{rl}-\tan\theta_{r'l}\mu_{r'l}-6\left(\frac{N_{(r-1)(r+1)}}{A_{(r-1)(r+1)}}+\frac{N_{(r-1)'(r+1)'}}{A_{(r-1)'(r+1)'}}\right)\right\}=6E\left(n\varepsilon t-\frac{\Delta}{\lambda}\right)(r=2,4,6,\cdots\cdots,n)$$

此の式に 3. で求めた N の値を入れて整理すれば (28) 式を得る。

$$x_r=-\left(\frac{1}{A_{13}l_{34}\cos\theta_{2l}}+\frac{1}{A_{35}l_{56}\cos\theta_{4l}}+\cdots\cdots+\frac{1}{A_{(n-1)(n+1)}l_{(n+1)(n+2)}\cos\theta_{nl}}\right)$$

$$p_{rl}=\frac{K_{(r-3)(r-1)}}{A_{(r-3)(r-1)}}\left(\frac{2}{l_{(r-1)r}\cos\theta_{(r-2)l}}+3\frac{\sin\theta_{(r-2)l}}{\lambda}\right)+\frac{K_{(r-1)(r+1)}}{A_{(r-1)(r+1)}}\left(\frac{1}{l_{(r+1)(r+2)}\cos\theta_{rl}}+3\frac{\sin\theta_{rl}}{\lambda}\right)$$

$$p_{ru}=\frac{K_{(r-2)r}}{A_{(r-3)(r-1)}}\frac{2}{l_{(r-1)r}\cos\theta_{(r-2)l}}+\frac{K_{r(r+2)}}{A_{(r-1)(r+1)}}\frac{1}{l_{(r+1)(r+2)}\cos\theta_{rl}}$$

$$q_{rl}=-\frac{1}{6}\tan\theta_{rl}+\frac{K_{(r-1)(r+1)}}{A_{(r-1)(r+1)}}\left(\frac{1}{l_{(r+1)(r+2)}\cos\theta_{rl}}+2\frac{\sin\theta_{rl}}{\lambda}\right)$$

$$q_{ru}=\frac{K_{r(r+2)}}{A_{(r-1)(r+1)}}\frac{1}{l_{(r+1)(r+2)}\cos\theta_{rl}}$$

$$s=\frac{1}{A_{13}\cos\theta_{2l}}+\frac{1}{A_{35}\cos\theta_{4l}}+\cdots\cdots+\frac{1}{A_{(n-1)(n+1)}\cos\theta_{nl}}+\frac{\lambda}{A_{13}l_{34}\cos\theta_{2l}}\tan\theta_{2l}$$
$$+\frac{\lambda}{A_{35}l_{56}\cos\theta_{4l}}(\tan\theta_{2l}+\tan\theta_{4l})+\cdots\cdots+\frac{\lambda}{A_{(n-1)(n+1)}l_{(n+1)(n+2)}\cos\theta_{nl}}(\tan\theta_{2l}$$
$$+\tan\theta_{4l}+\cdots\cdots+\tan\theta_{nl})+\frac{1}{A_{1'3'}\cos\theta_{2'l}}+\cdots\cdots+\frac{1}{A_{(n-1)'(n+1)'}\cos\theta_{n'l}}+\frac{\lambda}{A_{1'3'}l_{3'4'}\cos\theta_{2'l}}$$
$$\times\tan\theta_{2'l}+\cdots\cdots+\frac{\lambda}{A_{(n-1)'(n+1)'}l_{(n+1)'(n+2)'}\cos\theta_{n'l}}(\tan\theta_{2'l}+\tan\theta_{4'l}+\cdots\cdots+\tan\theta_{n'l})$$

$$t_r=\lambda\left(\frac{1}{A_{13}l_{34}\cos\theta_{2l}}+\frac{2}{A_{35}l_{56}\cos\theta_{4l}}+\cdots\cdots+\frac{\frac{n}{2}}{A_{(n-1)(n+1)}l_{(n+1)(n+2)}\cos\theta_{nl}}\right)$$

$$\xi=-\lambda\left(\frac{1}{A_{13}l_{34}\cos\theta_{2l}}+\frac{2}{A_{35}l_{56}\cos\theta_{4l}}+\cdots\cdots+\frac{\frac{n}{2}}{A_{(n-1)(n+1)}l_{(n+1)(n+2)}\cos\theta_{nl}}\right)P_2$$
$$-\lambda\left(\frac{1}{A_{35}l_{56}\cos\theta_{4l}}+\frac{2}{A_{57}l_{78}\cos\theta_{6l}}+\cdots\cdots+\frac{\frac{n}{2}-1}{A_{(n-1)(n+1)}l_{(n+1)(n+2)}\cos\theta_{nl}}\right)(P_3+P_4)$$
$$-\cdots\cdots-\lambda\left(\frac{1}{A_{(n-3)(n-1)}l_{(n-1)n}\cos\theta_{(n-2)l}}+\frac{2}{A_{(n-1)(n+1)}l_{(n+1)(n+2)}\cos\theta_{nl}}\right)(P_{n-3}+P_{n-2})$$
$$-\lambda\left(\frac{1}{A_{(n-1)(n+1)}l_{(n+1)(n+2)}\cos\theta_{nl}}\right)(P_{n-1}+P_n)-\lambda\left(\frac{1}{A_{1'3'}l_{3'4'}\cos\theta_{2'l}}+\frac{2}{A_{3'5'}l_{5'6'}\cos\theta_{4'l}}\right.$$

$$+\cdots\cdots+\frac{\frac{n}{2}}{A_{(n-1)'(n+1)'}l_{(n+1)'(n+2)'}\cos\theta_{n'l}}\Big)P_2'-\cdots\cdots$$
$$-\lambda\left(\frac{1}{A_{(n-1)'(n+1)'}l_{(n+1)'(n+2)'}\cos\theta_{n'l}}\right)(P_{(n-1)'}+P_n')$$

(b) 垂直方向:

$$V=\Sigma(l_{(r-1)(r+1)}\sin\theta_{rl}-l_{(r-1)'(r+1)'}\sin\theta_{r'l})$$
$$V'=\Sigma\{(l_{(r-1)(r+1)}+\Delta l_{(r-1)(r+1)})\sin(\theta_{rl}-\psi_{rl})-(l_{(r-1)'(r+1)'}+\Delta l_{(r-1)'(r+1)'})\sin(\theta_{r'l}+\psi_{r'l})\}$$
$$(r=2,4,6,\cdots\cdots,n)$$

水平方向の場合と同様に $\cos\psi_{rl}=1$, $\sin\psi_{rl}=\psi_{rl}$, $\cos\psi_{r'l}=1$, $\sin\psi_{r'l}=\psi_{r'l}$ とおき, $\Delta l_{(r-1)(r+1)}\psi_{rl}$, $\Delta l_{(r-1)'(r+1)'}\psi_{r'l}$ を含む項を省略すれば $V'-V$ は次のようになる。

$$V'-V=\Sigma(-l_{(r-1)(r+1)}\psi_{rl}\cos\theta_{rl}+\Delta l_{(r-1)(r+1)}\sin\theta_{rl}-l_{(r-1)'(r+1)'}\psi_{r'l}\cos\theta_{r'l}-\Delta l_{(r-1)'(r+1)'}\sin\theta_{r'l})=\Omega$$

この式に

$$l_{(r-1)(r+1)}=\frac{\lambda}{\cos\theta_{rl}},\quad l_{(r-1)'(r+1)'}=\frac{\lambda}{\cos\theta_{r'l}},\quad \Delta l_{(r-1)(r+1)}=\frac{N_{(r-1)(r+1)}}{EA_{(r-1)(r+1)}}\frac{\lambda}{\cos\theta_{rl}}+\varepsilon t\frac{\lambda}{\cos\theta_{rl}},$$
$$\Delta l_{(r-1)'(r+1)'}=\frac{N_{(r-1)'(r+1)'}}{EA_{(r-1)'(r+1)'}}\frac{\lambda}{\cos\theta_{r'l}}+\varepsilon t\frac{\lambda}{\cos\theta_{r'l}}$$

を入れ，両辺に $6E\frac{1}{\lambda}$ を乗ずれば

$$\Sigma\left\{\mu_{rl}+\mu_{r'l}+6\left(\frac{N_{(r-1)(r+1)}}{A_{(r-1)(r+1)}}\tan\theta_{rl}-\frac{N_{(r-1)'(r+1)'}}{A_{(r-1)'(r+1)'}}\tan\theta_{r'l}\right)\right\}=6E\left\{\frac{\Omega}{\lambda}-\varepsilon t\Sigma(\tan\theta_{rl}-\tan\theta_{r'l})\right\}$$
$$(r=2,4,6,\cdots\cdots,n)$$

この式に 3. で求めた N の値を入れて整理すれば(29)式を得る。

$$\overline{x_r}=-\left(\frac{\tan\theta_{2l}}{A_{13}l_{34}\cos\theta_{2l}}+\frac{\tan\theta_{4l}}{A_{35}l_{56}\cos\theta_{4l}}+\cdots\cdots+\frac{\tan\theta_{nl}}{A_{(n-1)(n+1)}l_{(n+1)(n+2)}\cos\theta_{nl}}\right)$$

$$\overline{p_{rl}}=\frac{K_{(r-3)(r-1)}}{A_{(r-3)(r-1)}}\left(\frac{2}{l_{(r-1)r}\cos\theta_{(r-2)l}}+3\frac{\sin\theta_{(r-2)l}}{\lambda}\right)\tan\theta_{(r-2)l}+\frac{K_{(r-1)(r+1)}}{A_{(r-1)(r+1)}}$$
$$\times\left(\frac{1}{l_{(r+1)(r+2)}\cos\theta_{rl}}+3\frac{\sin\theta_{rl}}{\lambda}\right)\tan\theta_{rl}$$

$$\overline{p_{ru}}=\frac{K_{(r-2)r}}{A_{(r-3)(r-1)}}\frac{2}{l_{(r-1)r}\cos\theta_{(r-2)l}}\tan\theta_{(r-2)l}+\frac{K_{r(r+2)}}{A_{(r-1)(r+1)}}\frac{1}{l_{(r+1)(r+2)}\cos\theta_{rl}}\tan\theta_{rl}$$

$$\overline{q_{rl}}=\frac{1}{6}+\frac{K_{(r-1)(r+1)}}{lA_{(r-1)(r+1)}}\left(\frac{1}{l_{(r+1)(r+2)}\cos\theta_{rl}}+2\frac{\sin\theta_{rl}}{\lambda}\right)\tan\theta_{rl}$$

$$\overline{q_{ru}}=\frac{K_{r(r+2)}}{A_{(r-1)(r+1)}}\frac{1}{l_{(r+1)(r+2)}\cos\theta_{rl}}\tan\theta_{rl}$$

$$\bar{s}=-\frac{\tan\theta_{2l}}{A_{13}\cos\theta_{2l}}-\frac{\tan\theta_{4l}}{A_{35}\cos\theta_{4l}}-\cdots\cdots-\frac{\tan\theta_{nl}}{A_{(n-1)(n+1)}\cos\theta_{nl}}-\frac{\lambda\tan\theta_{2l}}{A_{13}l_{34}\cos\theta_{2l}}\tan\theta_{2l}$$
$$-\frac{\lambda\tan\theta_{4l}}{A_{35}l_{56}\cos\theta_{4l}}(\tan\theta_{2l}+\tan\theta_{4l})-\cdots\cdots-\frac{\lambda\tan\theta_{nl}}{A_{(n-1)(n+1)}l_{(n+1)(n+2)}\cos\theta_{nl}}(\tan\theta_{2l}+\tan\theta_{4l}$$
$$+\cdots\cdots+\tan\theta_{nl})+\frac{\tan\theta_{2'l}}{A_{1'3'}\cos\theta_{2'l}}+\cdots\cdots+\frac{\tan\theta_{n'l}}{A_{(n-1)'(n+1)'}\cos_{n'l}}+\frac{\lambda\tan\theta_{2'l}}{A_{1'3'}l_{3'4'}\cos\theta_{2'l}}\tan\theta_{2'l}$$
$$+\cdots\cdots+\frac{\lambda\tan\theta_{n'l}}{A_{(n-1)'(n+1)'}l_{(n+1)'(n+2)'}\cos\theta_{n'l}}(\tan\theta_{2'l}+\tan\theta_{4'l}+\cdots\cdots+\tan\theta_{n'l})$$

$$\overline{t_r}=\lambda\left(\frac{\tan\theta_{2l}}{A_{13}l_{34}\cos\theta_{2l}}+\frac{2\tan\theta_{4l}}{A_{35}l_{56}\cos\theta_{4l}}+\cdots\cdots+\frac{\frac{n}{2}\tan\theta_{nl}}{A_{(n-1)(n+1)}l_{(n+1)(n+2)}\cos\theta_{nl}}\right)$$

$$\bar{\xi}=\lambda\left(\frac{\tan\theta_{2l}}{A_{13}l_{34}\cos\theta_{2l}}+\frac{2\tan\theta_{4l}}{A_{35}l_{56}\cos\theta_{4l}}+\cdots\cdots+\frac{\frac{n}{2}\tan\theta_{nl}}{A_{(n-1)(n+1)}l_{(n+1)(n+2)}\cos\theta_{nl}}\right)P_2$$
$$+\lambda\left(\frac{\tan\theta_{4l}}{A_{35}l_{56}\cos\theta_{4l}}+\frac{2\tan\theta_{6l}}{A_{57}l_{78}\cos\theta_{6l}}+\cdots\cdots+\frac{\left(\frac{n}{2}-1\right)\tan\theta_{nl}}{A_{(n-1)(n+1)}l_{(n+1)(n+2)}\cos\theta_{nl}}\right)(P_3+P_4)$$
$$+\cdots\cdots\cdots\cdots$$

$$+\lambda\left(\frac{\tan\theta_{(n-2)l}}{A_{(n-3)(n-1)}l_{(n-1)n}\cos\theta_{(n-2)l}}+\frac{2\tan\theta_{nl}}{A_{(n-1)(n+1)}l_{(n+1)(n+2)}\cos\theta_{nl}}\right)(P_{n-3}+P_{n-2})$$

$$+\lambda\left(\frac{\tan\theta_{nl}}{A_{(n-1)(n+1)}l_{(n+1)(n+2)}\cos\theta_{nl}}\right)(P_{n-1}+P_n)-\lambda\left(\frac{\tan\theta_2'{}_l}{A_1'{}_3'l_3'{}_4'\cos\theta_2'{}_l}+\frac{2\tan\theta_4'{}_l}{A_3'{}_5'l_5'{}_6'\cos\theta_4'{}_l}+\cdots\cdots\right.$$

$$\left.+\frac{\frac{n}{2}\tan\theta_n'{}_l}{A_{(n-1)'(n+1)'}l_{(n+1)'(n+2)'}\cos\theta_n'{}_l}\right)P_2'-\cdots\cdots-\lambda\left(\frac{\tan\theta_n'{}_l}{A_{(n-1)'(n+1)'}l_{(n+1)'(n+2)'}\cos\theta_n'{}_l}\right)$$

$$\times(P_{(n-1)'}+P_n')$$

$$\Sigma(\tan\theta_{rl}-\tan\theta_r'{}_l)=(\tan\theta_{2l}-\tan\theta_2'{}_l)+(\tan\theta_{4l}-\tan\theta_4'{}_l)+\cdots\cdots+(\tan\theta_{nl}-\tan\theta_n'{}_l)$$

以上の各記号に於ける n は橋の左側に於ては中央の垂直材より左側にある格間の数の2倍を，橋の右側に於ては中央の垂直材より右側にある格間の数の2倍を表わす。この例に於ては橋の左側，右側ともに $n=6$ である。

5. むすび

格間数7の場合も同様に連立方程式の表を求める事が出来る。任意の格間数の場合に対しては，上のようにして求めた格間数6，7の場合を推し進めれば機械的に連立方程式の表が求まる。

かくして求めた各方程式は荷重，温度変化ともにその影響を考慮したもので，之に依り荷重，温度の両応力を一度に求める事が出来る。之等を別々に解きたい時には，荷重応力に対しては (28) 式の右辺の $6E\varepsilon t$，及び (29)式の右辺の $-E\varepsilon t\Sigma(\tan\theta_{rl}-\tan\theta_r'{}_l)$を除き，温度応力に対しては右辺の $\alpha_r, \beta_r, \gamma_r, \delta_r, \varepsilon_r, \zeta_r, \eta, \nu, \xi, \rho$, を除き且つ $\Sigma P=0$, $[A]=-[H]\tan\alpha$ (α は支点 1, 1′ を結ぶ線の水平となす角度) とおき (29) 式を省略すれば良い。

上弦材水平な場合は，各方程式に於て $\theta_{ru}=0$ とおけば良く，又2ヒンジアーチ橋の場合は $M_1=0$, $M_1'=0$ とおき，Φ_1, Φ_1' を未知数とし，垂直反力 A を既知数とすれば良い。

フィレンデールトラス橋の場合は $M_1=0$, $M_1'=0, H=0$ とおき，Φ，Φ_1' を未知数とし，垂直反力 A を既知数とすれば良い。尚下弦材水平，上弦材曲弦のフィレンデールトラス橋の場合は更に $\theta_{rl}=0$ とおけば良く，上下弦材共水平な所謂平行弦フィレンデールトラス橋の場合は $\theta_{rl}=0$, $\theta_{ru}=0$ とおけば良い。即ちフィレンデール固定アーチ橋に対する**表—1** の形の連立方程式よりあらゆる型のフィレンデール型橋梁の応力を求めるための連立方程式が誘導出来る。

尚本解法に依ればリブアーチ橋に於て，床版，支柱或いは床版，吊材がリブの応力に及ぼす影響を明らかにする事が出来る。

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