耐震壁の Stiffness Matrix の実用算定法(第2報)

——基本 Flexibility Matrix の実用算定法——

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紙面の都合で本論文は2編に分割され、第1報 基本 Flexibility Matrix および基本 Stiffness Matrix の各要素の性状(§1, §2) はすでに日本建築学会論文報告集第278号昭和54年4月に発表した。

なお、本論文の目的は第1報 §1 序説を参照されたい。

§3 基本 Flexibility Matrix の要素を求める補間式

Stiffness Matrix $\bar{K}$ および基本 Flexibility Matrix F^* の全要素は、ヤング係数 E 、階高 h および壁厚 t に関する項でこれをくくると、無次元化され(第1報の1および3式参照)、無次元量である5個の形状係数 λ , α_a , α_b , β_a , β_b だけの関数で与えられる(第1報の §1 および Fig. 2 参照)。

そこで、特定の形状係数を有する基準耐震壁の F^* の要素の弾性解を用意しておき、この基準値より順次各形状係数に対する補間を繰り返すことによって任意の形状係数を有する耐震壁の F^* を求める。

第1報で示した形状係数が F^* の要素におよぼす影響の考察により、補間の方法は、柱・はりの断面形状に関する形状係数 α_a , α_b , β_a , β_b に対しては、 F^* の全要素とも双曲線補間を行ない、形状係数の辺長比 λ に対しては、 F^* の要素ごとに λ の値域に応じて Table 7 に定められた補間式を使う。また補間の順序は、補間誤差の少ない形状変数から行なうという原則のもとに、 F^* の全要素とも $\beta_a \rightarrow \beta_b \rightarrow \alpha_a \rightarrow \alpha_b \rightarrow \lambda$ の順序で補間をする(第1報の §2, Table 3 および Table 5 参照)。

α_a , α_b , β_a , β_b のいずれかを変数 x として与えられる F^* の要素の補間値 $f(x)$ は、変数 x およびその値域の最小値 x_1 , 中間値 x_2 , 最大値 x_3 に対応する要素の既知の値 $f(x_1)$, $f(x_2)$, $f(x_3)$ によって9式のように表わすことができる(Fig. 9 参照)。ただし、 x 以外の形状係数は λ も含めて特定の値に固定されている。

ここで

$$\bar{x} = \frac{x - x_1}{x_2 - x_1} + 1, \quad x_3 - x_2 = x_2 - x_1$$

である。

$$f(x) = f(x_2) + \frac{2\{f(x_2) - f(x_1)\}\{f(x_3) - f(x_2)\}(\bar{x} - 2)}{-\{f(x_3) - 2f(x_2) + f(x_1)\}\bar{x} + 3f(x_3) - 4f(x_2) + f(x_1)} \dots\dots\dots (9)$$

Fig. 9 Interpolation of hyperbolic function $f(x)$

辺長比 λ が変数となっている場合の F^* の要素の補間式を各要素ごとに、 λ の値域に応じて Table 7 に示した。この場合も他の形状係数は特定の値に固定されている。Table 7 中、ハッチをした値域に λ がある場合の補間式は、その値域の λ の最小値と最大値に対応する要素の値2個をあらかじめ求めておく必要があり、ハッチしてない値域に λ がある場合は、 λ の値に関係なく F^* の要素の値は一定の値をとるとみなせるので、その値域内の特定の λ に対する要素の値があらかじめ求められていれば充分である。

従って、 $1 \leq \lambda \leq 3$ の全ての λ に対して F^* の全要素を求めるためには30個の要素が必要である(Table 7 参照)。

1回の双曲線補間に3個のデータが必要であるから、柱・はりの断面に関する4個の形状係数に対して順次双曲線補間を行なうには、Table 7 中の30個の要素の各々について、

$$\begin{aligned} \alpha_a &= 0.1, 0.2, 0.3 & \alpha_b &= 0.1, 0.2, 0.3 \\ \beta_a &= 2, 4, 6 & \beta_b &= 2, 4, 6 \end{aligned}$$

の全ての組合せの計81個の値が必要となる。

従って、 $1 \leq \lambda \leq 3$ の場合に対して F^* の全要素が補間できるためには、 $30 \times 81 = 2430$ 個の既知の解析解が必要であり、その数表を Table 8~Table 10 に示す。表中たとえば、 $2.373-2$ とは 2.373×10^{-2} を意味する。

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(昭和53年6月2日本稿受理・討論期限昭和54年8月末日)

Table 7 Appropriate interpolation formulae of each element of F^* , corresponding to the range of λ

λ	1	1.5	1.75	2	3	*3
*1	29	27	26	21		
*2						
a_{11}	$a_{11} _{\lambda=1.5}$					1
a_{12}	$a_{12} _{\lambda=1} + \frac{\lambda-1}{2} (a_{12} _{\lambda=3} - a_{12} _{\lambda=1})$					2
a_{22}	$a_{22} _{\lambda=1} \left(\frac{a_{22} _{\lambda=2}}{a_{22} _{\lambda=1}} \right)^{\frac{\log \lambda}{\log 2}}$			$a_{22} _{\lambda=2} \left(\frac{a_{22} _{\lambda=3}}{a_{22} _{\lambda=2}} \right)^{\frac{\log \lambda/2}{\log 1.5}}$		3
b_{11}	$b_{11} _{\lambda=1} + \frac{\lambda-1}{2} (b_{11} _{\lambda=3} - b_{11} _{\lambda=1})$					2
b_{12}	$b_{12} _{\lambda=1.75} + \left(\frac{1.75-\lambda}{0.75} \right)^{2.5} (b_{12} _{\lambda=1} - b_{12} _{\lambda=1.75})$			$b_{12} _{\lambda=1.75}$		2
b_{13}	$b_{13} _{\lambda=1} + (\lambda-1) (b_{13} _{\lambda=2} - b_{13} _{\lambda=1})$			$b_{13} _{\lambda=2}$		2
b_{22}	$b_{22} _{\lambda=1} + (\lambda-1) (3-\lambda) (b_{22} _{\lambda=2} - b_{22} _{\lambda=1})$			$b_{22} _{\lambda=2}$		2
b_{23}	$b_{23} _{\lambda=1} + 4(\lambda-1)(2-\lambda) (b_{23} _{\lambda=1.5} - b_{23} _{\lambda=1})$			$b_{23} _{\lambda=1.5}$		2
b_{33}	$b_{33} _{\lambda=1} + (\lambda-1) (b_{33} _{\lambda=2} - b_{33} _{\lambda=1})$			$b_{33} _{\lambda=2}$		2
c_{11}	$c_{11} _{\lambda=1} + (\lambda-1) (3-\lambda) (c_{11} _{\lambda=2} - c_{11} _{\lambda=1})$			$c_{11} _{\lambda=2}$		2
c_{12}	$c_{12} _{\lambda=1} + 4(\lambda-1)(2-\lambda) (c_{12} _{\lambda=1.5} - c_{12} _{\lambda=1})$			$c_{12} _{\lambda=1.5}$		2
c_{22}	$c_{22} _{\lambda=1} + (\lambda-1) (c_{22} _{\lambda=2} - c_{22} _{\lambda=1})$			$c_{22} _{\lambda=2}$		2
d_{11}	$d_{11} _{\lambda=1} + \frac{\lambda-1}{2} (d_{11} _{\lambda=3} - d_{11} _{\lambda=1})$					2
d_{12}	$d_{12} _{\lambda=1} + \frac{\lambda-1}{2} (d_{12} _{\lambda=3} - d_{12} _{\lambda=1})$					2
d_{22}	$d_{22} _{\lambda=1} + \frac{\lambda-1}{2} (d_{22} _{\lambda=3} - d_{22} _{\lambda=1})$					2

Notes : *1 Number of the required given values of all the elements of F^* , to calculate all the elements by interpolation, corresponding to the range of λ

2 Elements of F^

3 Number of the required given values of each element of F^

Fig. 10 The absolute error $|R|$ of each interpolated element b_{13} corresponding to various A_a/A_b (for $\lambda=1.25$)

Fig. 11 The absolute error $|R|$ of each interpolated element b_{13} corresponding to various A_a/A_b (for $\lambda=1.5$)

Table 9 Analytical values of each element of F^* for the combinations of the basic values of λ , α_a , α_b and β_a , where $\beta_b=4$

[illegible]

α_2	α_1	α_0	$b_{233h=15}$	$b_{333h=2}$	$C_{111h=1}$	$C_{111h=2}$	$C_{121h=1}$	$C_{121h=2}$	$C_{221h=1}$	$C_{221h=2}$	$d_{111h=1}$	$d_{111h=3}$	$d_{121h=3}$	$d_{221h=1}$	$d_{221h=3}$
2	0.1	0.1	-1.851	7.419	1.7343	6.3561	-1.923	-1.835	7.256	17.338	1.540	4.643	0.114	7.363	18.587
	0.2	0.1	-1.370	6.643	1.5711	5.4851	-1.475	-1.350	3.468	3.555	1.948	2.986	0.654	3.532	14.336
	0.3	0.1	-1.028	2.122	1.2076	1.6951	-1.174	-1.014	2.003	2.061	1.6722	1.253	0.419	1.986	1.2.584
0.2	0.2	0.1	-1.736	2.955	2.898	3.5011	-1.348	-1.7522	2.832	2.896	1.305	4.409	0.935	2.784	14.022
	0.2	0.2	-6.043	1.876	1.811	3.1001	-6.590	-4.958	1.730	1.805	1.8297	2.868	0.937	1.659	12.469
	0.3	0.3	-6.941	1.275	1.223	2.7071	-6.625	-4.8751	1.148	1.214	1.5945	1.249	0.412	1.054	1.646
0.3	0.1	0.3	-3.407	1.495	1.453	2.3511	-3.665	-3.3781	1.406	1.452	1.118	4.223	0.754	1.463	12.701
	0.2	0.2	-3.118	1.080	1.031	2.1041	-3.076	-3.4081	1.705	1.028	1.2797	2.759	0.548	0.915	10.173
	0.3	0.3	-2.692	1.803	1.601	1.8401	-3.163	-2.678	6.977	7.544	5.1971	2.001	0.067	6.455	0.1.268
4	0.1	0.1	-1.765	5.922	1.5863	6.2502	-1.1875	-1.1760	5.789	15.855	1.9078	2.820	0.633	5.806	16.554
	0.2	0.2	-1.306	2.738	1.2632	1.6671	-1.418	-1.279	2.509	2.623	1.5093	1.625	0.343	2.628	13.059
	0.3	0.3	-9.704	1.538	1.461	1.4911	-1.123	-0.9423	1.394	1.442	3.4951	1.123	0.198	1.430	1.1.751
0.2	0.2	0.2	-7.009	2.532	2.488	3.4921	-7.4607	-7.0021	2.430	2.484	1.8707	2.700	0.960	2.1286	13.047
	0.2	0.2	-5.970	1.528	1.447	1.3091	-6.6031	-5.8511	1.345	1.441	4.4971	1.566	0.981	1.301	1.1.740
	0.3	0.3	-4.840	1.989	0.251	2.7001	-5.6181	-4.6981	8.198	9.119	3.1001	1.083	0.593	8.029	0.1.115
0.3	0.3	0.3	-3.457	1.343	1.306	2.3691	-3.8351	-3.4611	1.259	1.303	1.8081	2.593	0.534	1.191	1.1.953
	0.2	0.2	-3.201	1.940	8.724	2.1001	-3.6691	-3.1581	7.912	0.685	3.9231	1.508	0.325	7.465	0.1.189
	0.3	0.3	-2.748	6.191	6.094	1.8361	-3.3221	-2.7071	5.235	6.010	2.7091	1.044	0.271	4.934	0.0.036
6	0.1	0.1	-1.726	5.694	1.5138	6.4441	-1.851	-1.727	5.065	15.130	1.6481	2.027	0.851	5.605	15.605
	0.2	0.2	-1.288	2.317	1.2194	1.56371	-1.379	-1.231	2.053	2.184	1.3487	1.117	0.760	2.219	12.511
	0.3	0.3	-9.257	1.260	1.183	1.48951	-1.093	-0.8931	1.067	1.158	2.3861	7.5991	3.931	1.177	1.1.409
0.2	0.1	0.2	-6.961	2.317	2.278	3.4871	-7.6601	-6.9941	2.219	2.271	5.6371	1.946	1.379	0.4140	12.601
	0.2	0.2	-5.928	1.358	1.263	3.0871	-6.5831	-5.7671	1.143	1.255	3.0871	1.077	0.563	1.2194	0.1.143
	0.3	0.3	-4.732	1.850	0.793	2.6961	-5.5871	-4.5581	6.609	7.617	2.0981	7.3301	1.422	6.896	0.9.066
0.3	0.1	0.3	-3.489	1.260	1.226	2.3661	-3.931	-3.5171	1.177	1.223	1.872	1.093	0.855	1.067	1.1.817
	0.2	0.2	-3.246	1.8580	7.857	0.20981	-3.1851	-2.9861	6.896	7.815	2.6961	1.037	0.5871	6.609	0.9.634
	0.3	0.3	-2.748	1.5952	0.298	1.8341	-3.7601	-2.69991	4.296	5.186	1.8341	7.0661	3.4061	4.296	0.6.423

な耐震壁であり、No. 38 は柱・はりの断面形状が No. 37 と等しく、 $\lambda=0.75$ とした耐震壁である。No. 39 は要素 b_{13} の補間誤差が大きくなる形状である（第 1 報 § 2, Table 5 参照）。

39 形状のうち, No. 1~No. 38 は, 5 つの形状係数のすべてに対して補間を行なうので, 累積誤差が生じる場合であり, No. 39 は λ に対する単一の補間誤差が F^* の多くの要素に対して大きくなる場合である。

4.2 累積誤差の検討

Table 12 に示した 39 形状について, § 3 で示した補間式によって順次補間を行なって求めた F^* の要素

の解析解²⁾ に対する累積誤差 $R(\%)$ と各要素の最大累積誤差 $(\%)$ を Table 13 に示す。

$$R(\%) = \left(\frac{\text{F}^* \text{の要素の略算値}}{\text{F}^* \text{の要素の解析解}} - 1 \right) \times 100 \quad \dots\dots\dots (10)$$

要素ごとにその累積誤差を検討してみると以下のようになる。

- 1) 要素 a_{11} , a_{22} は最大 3%, a_{12} は最大 4% 生じている。いずれも、はりせい・柱せいが共に小さい値のときに大きな累積誤差を生じている。
- 2) 要素 b_{11} は最大 1%, b_{22} は最大 2%, b_{33} b_{12} は

Table 10 Analytical values of each element of F^* for the combinations of the basic values of λ , α_a , α_b and β_a , where $\beta_b=6$

β_a	α_b	α_a	$d_{11}\lambda=15$	$d_{12}\lambda=15$	$d_{22}\lambda=15$	$d_{11}\lambda=3$	$d_{12}\lambda=3$	$d_{22}\lambda=3$	$b_{11}\lambda=1$	$b_{11}\lambda=3$	$b_{12}\lambda=1$	$b_{12}\lambda=3$	$b_{22}\lambda=1$	$b_{22}\lambda=3$	$d_{11}\lambda=75$	$b_{13}\lambda=1$	$b_{13}\lambda=3$	$d_{13}\lambda=2$	$b_{23}\lambda=1$	$b_{23}\lambda=3$
2	0.1	0.1	-1.782	-1.715	-1.715	1.915	1.810	1.889	1.347	2.889	-2.754	-3.079	4.451	4.395	4.395	4.451	4.395	4.395	4.395	4.395
		0.2	-1.782	-1.715	-1.715	1.915	1.810	1.889	1.347	2.889	-2.754	-3.079	4.451	4.395	4.395	4.451	4.395	4.395	4.395	4.395
		0.3	-1.782	-1.715	-1.715	1.915	1.810	1.889	1.347	2.889	-2.754	-3.079	4.451	4.395	4.395	4.451	4.395	4.395	4.395	4.395
		0.2	-1.782	-1.715	-1.715	1.915	1.810	1.889	1.347	2.889	-2.754	-3.079	4.451	4.395	4.395	4.451	4.395	4.395	4.395	4.395
	0.2	0.1	-1.782	-1.715	-1.715	1.915	1.810	1.889	1.347	2.889	-2.754	-3.079	4.451	4.395	4.395	4.451	4.395	4.395	4.395	4.395
		0.2	-1.782	-1.715	-1.715	1.915	1.810	1.889	1.347	2.889	-2.754	-3.079	4.451	4.395	4.395	4.451	4.395	4.395	4.395	4.395
		0.3	-1.782	-1.715	-1.715	1.915	1.810	1.889	1.347	2.889	-2.754	-3.079	4.451	4.395	4.395	4.451	4.395	4.395	4.395	4.395
		0.2	-1.782	-1.715	-1.715	1.915	1.810	1.889	1.347	2.889	-2.754	-3.079	4.451	4.395	4.395	4.451	4.395	4.395	4.395	4.395
	0.3	0.1	-1.782	-1.715	-1.715	1.915	1.810	1.889	1.347	2.889	-2.754	-3.079	4.451	4.395	4.395	4.451	4.395	4.395	4.395	4.395
		0.2	-1.782	-1.715	-1.715	1.915	1.810	1.889	1.347	2.889	-2.754	-3.079	4.451	4.395	4.395	4.451	4.395	4.395	4.395	4.395
		0.3	-1.782	-1.715	-1.715	1.915	1.810	1.889	1.347	2.889	-2.754	-3.079	4.451	4.395	4.395	4.451	4.395	4.395	4.395	4.395
		0.2	-1.782	-1.715	-1.715	1.915	1.810	1.889	1.347	2.889	-2.754	-3.079	4.451	4.395	4.395	4.451	4.395	4.395	4.395	4.395

No. 39 で 4% 他の形状で 2% である。

要素 b_{13} は No. 39 で 8%, $\lambda=1.25$ でありせいが大きくかつ柱せいが小さいときに最大 5%, 他の形状では 2% 以内である。

要素 b_{23} は $\lambda=0.75$ でありせいが小さくかつ柱せいが大きいときに最大 5%, 他の形状では 3% 以内におさまっている。

- 要素 c_{11} , c_{12} は最大 1%, c_{22} は No. 39 で 5% 他の形状で 3% 以内である。
- 要素 d_{11} , d_{12} は最大 1%, d_{22} は最大 3% である。

- 柱・はりの断面形状が標準的な場合 (Table 12 中 No. 37, No. 38 の形状) は, すべての要素が最大 1% 程度の精度で求まっている。

§5 補間値の補正を行なった基本 Flexibility Matrix の実用算定法

4.2 の累積誤差の検討より, 適用範囲内では F^* のほとんどの要素が, 5% 以内の精度で求まっているが, $1 \leq \lambda \leq 2 \left(\frac{1}{2} \leq \lambda \leq 1 \right)$ の場合で, 柱 (はり) 断面よりはり (柱) 断面が著しく大きいときに要素 b_{13} (b_{23}) に 5% を越す誤差を生じることが明らかにされた。

Table 11 Relations between the elements of F^* of a given shear wall and those of the permuted shear wall

$a_{11}=a_{22} \lambda'$	$a_{12}=a_{12} \lambda'$	$a_{23}=a_{11} \lambda'$	$b_{11}=b_{22} \lambda'$	$b_{12}=b_{12} \lambda'$
$b_{13}=-\frac{b_{23} \lambda'}{\lambda}$	$b_{22}=b_{11} \lambda'$	$b_{23}=-\frac{b_{13} \lambda'}{\lambda}$	$b_{33}=\frac{b_{33} \lambda'}{\lambda^2}$	$c_{11}=d_{11} \lambda'$
$c_{12}=-\frac{d_{12} \lambda'}{\lambda}$	$c_{22}=\frac{d_{22} \lambda'}{\lambda^2}$	$d_{11}=c_{11} \lambda'$	$d_{12}=-\frac{c_{12} \lambda'}{\lambda}$	$d_{22}=\frac{c_{22} \lambda'}{\lambda^2}$

Note : The symbols defined by $|\lambda'$ express the elements of F^* of the permuted shear wall

そこで、Table 14 に示した柱・はりの断面形状に対して $1 \leq \lambda \leq 2$ の場合で b_{13} の誤差 $R(\%)$ の検討をした結果、 $\lambda=1.25$ および $\lambda=1.5$ で 5% を越す $|R|$ を生じることが分かった。 $|R|$ と、はり・柱の断面積の比 $A_a/A_b (= \alpha_a \beta_a / \alpha_b \beta_b)$ との関係をそれぞれ Fig. 10, Fig. 11 に示した。Fig. 10 および Fig. 11 中には b_{13} 以外の F^* の要素の最大誤差も比較のため示している。Fig. 10 より、 $\lambda=1.25$ の場合、 $|R|$ の平均値 $|R|_{ave}(\%)$ は 11 式で、また Fig. 11 より、 $\lambda=1.5$ の場合、 $|R|_{ave}(\%)$ は 12 式でそれぞれ与えることができる。

$$|R|_{ave} = 2.6 + 0.6 \frac{A_a}{A_b} \quad (\lambda=1.25) \dots\dots\dots (11)$$

$$|R|_{ave} = 1.6 + 0.6 \frac{A_a}{A_b} \quad (\lambda=1.5) \dots\dots\dots (12)$$

R は負の値となることが多く、また、正の値をとる場合でも、最大 1% 前後にとどまっている。そこで、 $1 < \lambda < 2$ の場合は b_{13} に負の補間誤差を生ずると見なして補間値の補正を試みる。

補正の方法として、 $\lambda=1$ および $\lambda=2$ の場合は補正量は（誤差は）0 とし、 $\lambda=1.25$ 、および $\lambda=1.5$ の場合は、それぞれ式 11 および 12 で与えられる $|R|_{ave}$ とし、 $1 \leq \lambda \leq 2$ の場合の λ に対する補正量は $\lambda=1$ 、1.25、1.5、2 に対する上記の補正量より直線補間により求めることにすると、 λ の 3 つの値域に応じて 13、14 および 15 式が得られる。

i) $1 \leq \lambda < 1.25$ の場合

$$b_{13}' = \frac{b_{13}}{1 - \frac{\lambda-1}{25} \left(2.6 + 0.6 \frac{A_a}{A_b} \right)} \dots\dots\dots (13)$$

但し、 b_{13} =要素 b_{13} の補間値

b_{13}' =要素 b_{13} の補正值

ii) $1.25 \leq \lambda < 1.5$ の場合

$$b_{13}' = \frac{b_{13}}{1 - \frac{1}{100} \left(2.6 + 0.6 \frac{A_a}{A_b} \right) + \frac{\lambda-1.25}{25}} \dots\dots\dots (14)$$

iii) $1.5 \leq \lambda \leq 2$ の場合

$$b_{13}' = \frac{b_{13}}{1 + \frac{\lambda-2}{50} \left(1.6 + 0.6 \frac{A_a}{A_b} \right)} \dots\dots\dots (15)$$

$\frac{1}{2} \leq \lambda \leq 1$ の場合は、 b_{23} は $1 \leq \lambda \leq 2$ の場合の b_{13}

Table 12 Shapes of the 39 shear walls adopted for the investigation of the errors of the interpolated values of the elements of F^*

No.	Aspect ratios					Dimensions for $h=350\text{cm}$ and $t=18\text{cm}$				
	λ	α_a	α_b	β_a	β_b	l [cm]	D_a [cm]	D_b [cm]	B_a [cm]	B_b [cm]
1	0.75	0.125	0.125	2.5	2.5	262.5	43.75	43.75	45	45
2	"	0.206	"	"	"	"	72.18	"	"	"
3	"	0.125	0.206	"	"	"	43.75	72.18	"	"
4	"	0.206	"	"	"	"	72.18	"	"	"
5	"	0.125	0.125	"	5.5	"	43.75	43.75	"	99
6	"	0.206	"	"	"	"	72.18	"	"	"
7	"	0.125	0.206	"	"	"	43.75	72.18	"	"
8	"	0.206	"	"	"	"	72.18	"	"	"
9	"	0.125	0.125	3.5	"	"	43.75	43.75	63	"
10	"	0.206	"	"	"	"	72.18	"	"	"
11	"	0.125	0.206	"	"	"	43.75	72.18	"	"
12	"	0.206	"	"	"	"	72.18	"	"	"
13	1.25	0.125	0.125	2.5	2.5	437.5	43.75	43.75	45	45
14	"	0.275	"	"	"	"	96.25	"	"	"
15	"	0.125	0.275	"	"	"	43.75	96.25	"	"
16	"	0.275	"	"	"	"	96.25	"	"	"
17	"	0.125	0.125	"	5.5	"	43.75	43.75	"	99
18	"	0.275	"	"	"	"	96.25	"	"	"
19	"	0.125	0.275	"	"	"	43.75	96.25	"	"
20	"	0.275	"	"	"	"	96.25	"	"	"
21	"	0.125	0.125	3.5	"	"	43.75	43.75	63	"
22	"	0.275	"	"	"	"	96.25	"	"	"
23	"	0.125	0.275	"	"	"	43.75	96.25	"	"
24	"	0.275	"	"	"	"	96.25	"	"	"
25	2.75	0.125	0.125	2.5	2.5	962.5	43.75	43.75	45	45
26	"	0.275	"	"	"	"	96.25	"	"	"
27	"	0.125	0.275	"	"	"	43.75	96.25	"	"
28	"	0.275	"	"	"	"	96.25	"	"	"
29	"	0.125	0.125	"	5.5	"	43.75	43.75	"	99
30	"	0.275	"	"	"	"	96.25	"	"	"
31	"	0.125	0.275	"	"	"	43.75	96.25	"	"
32	"	0.275	"	"	"	"	96.25	"	"	"
33	"	0.125	0.125	3.5	"	"	43.75	43.75	63	"
34	"	0.275	"	"	"	"	96.25	"	"	"
35	"	0.125	0.275	"	"	"	43.75	96.25	"	"
36	"	0.275	"	"	"	"	96.25	"	"	"
37	1.71	0.171	0.171	2.5	3.3	600.0	60.00	60.00	45	60
38	0.75	"	"	"	"	262.5	"	"	"	"
39	1.25	0.300	0.100	6.0	2.0	437.5	105.0	35.00	108	36

より求まるから（§3 参照）、この操作により、 b_{23} の補正も行なうことができる。

Fig. 10 および Fig. 11 に示した $|R|$ と A_a/A_b との関係について、上記の補正を行なった結果を Fig. 12 および Fig. 13 に示す。この結果、 $|R|$ は 4% 以下におさまっている。Table 13 に掲げた No. 14 の b_{13} および No. 7 の b_{23} の誤差も上記の補正により 1% 以内となっている。

以上の補正により、 F^* の全要素の累積誤差が λ が値域内のどの値をとっても 5% 以内に納まることになった。また、 A_a/A_b が 4 以上あるいは $\frac{1}{4}$ 以下となることは通常の建築物ではほとんどないと考えられるから、このことを考慮すると一般的な形状の耐震壁の F^* の

Table 13 Errors (%) of the interpolated values of the elements of F^*

No.	a ₁₁	a ₁₂	a ₂₂	b ₁₁	b ₁₂	b ₁₃	b ₂₂	b ₂₃	b ₃₃	c ₁₁	c ₁₂	c ₂₂	d ₁₁	d ₁₂	d ₂₂
1	-1.2	-1.3	-0.7	-0.3	-0.5	-0.3	-0.7	-1.5	0.2	0.0	-0.2	-0.1	0.6	-0.4	-0.6
2	-0.2	1.0	1.0	-0.1	-0.6	-0.3	-0.3	0.4	1.4	0.0	0.2	1.2	0.2	-0.3	-0.7
3	0.2	0.1	0.3	-0.0	-0.4	0.7	-0.6	-3.3	-0.1	0.0	-0.1	0.3	0.5	-0.1	1.5
4	0.1	1.6	1.1	0.2	-0.6	0.5	-0.2	-1.2	0.4	0.0	0.0	1.0	0.0	-0.2	0.4
5	-2.9	-2.3	-0.8	-0.1	0.4	-0.2	-0.8	-2.5	0.2	0.0	-0.2	0.0	0.5	-0.7	-1.8
6	-2.6	-0.5	0.7	0.2	0.1	-0.4	-0.5	-0.4	1.4	0.0	0.2	1.4	0.1	-0.7	-2.2
7	-0.9	1.0	0.2	0.6	0.8	1.1	-0.5	-4.5	-1.3	0.0	0.1	-0.6	0.2	-0.5	1.9
8	-1.8	2.4	0.9	0.8	0.3	1.4	-0.3	-2.4	-0.8	0.0	0.4	0.0	-0.3	-0.6	0.3
9	-2.8	-2.5	-1.1	-0.1	0.0	-0.3	-0.5	-1.8	0.4	0.0	-0.2	-0.3	0.3	-0.7	-2.1
10	-2.3	-0.3	0.7	0.2	-0.3	-0.3	-0.2	0.4	1.3	0.0	0.2	1.3	-0.0	-0.6	-2.6
11	-1.1	0.5	-0.2	0.5	0.1	1.0	-0.3	-3.3	-0.8	0.0	0.1	-0.8	0.0	-0.3	0.9
12	-1.8	2.3	0.8	0.7	-0.4	1.5	-0.1	-0.9	-0.6	0.0	0.4	0.1	-0.4	-0.5	-0.8
13	-1.7	-2.3	-2.1	-0.9	-0.7	-1.8	-0.4	-0.7	-0.7	0.7	-0.3	-1.2	0.0	-0.5	-1.1
14	0.3	0.7	0.4	-0.8	-0.1	-4.1	-0.0	0.7	-0.4	0.7	0.2	2.2	0.1	-0.2	0.2
15	1.1	0.6	0.1	-0.3	-1.1	0.4	-0.1	-0.8	1.3	0.3	0.0	-0.4	0.0	0.2	1.2
16	1.2	1.7	0.1	-0.3	-0.9	-1.6	0.3	0.2	0.1	0.0	0.1	0.6	0.0	0.1	1.0
17	-3.0	-3.6	-2.4	-0.5	-1.1	-1.3	-0.3	-1.0	-0.6	0.3	-0.5	-1.4	0.0	-0.6	-2.2
18	-1.1	-0.8	-0.1	-0.3	-1.0	-2.8	-0.1	0.3	0.2	0.3	0.4	1.1	0.0	-0.2	-0.7
19	1.4	1.0	0.7	0.2	-1.0	1.1	0.0	0.2	0.8	0.0	0.4	-0.9	-0.1	0.1	1.1
20	1.3	1.8	0.4	0.1	-1.4	0.4	0.2	0.9	-0.1	-0.2	0.1	-0.7	0.0	0.1	1.0
21	-2.9	-3.7	-2.8	-0.6	-0.7	-1.7	-0.3	-0.9	-0.6	0.3	-0.6	-1.7	0.1	-0.6	-2.1
22	-1.0	-0.5	-0.5	-0.3	-0.7	-2.8	0.1	0.4	-0.1	0.2	0.3	0.9	0.0	-0.1	-0.9
23	1.2	0.6	0.1	0.0	-0.8	0.8	0.0	-0.2	0.7	0.0	0.1	-1.3	-0.0	0.1	1.2
24	1.2	1.9	-0.5	0.0	-1.4	0.4	0.3	1.0	-0.4	-0.2	0.3	1.1	-0.0	0.2	0.8
25	-1.8	-1.8	-1.4	0.1	0.4	-0.4	0.0	-0.1	-0.8	0.1	-0.8	-0.9	0.0	-0.3	-1.2
26	0.2	0.3	0.5	0.0	0.9	0.7	-0.1	0.5	1.4	0.2	-0.1	0.5	0.0	-0.1	0.4
27	1.0	1.0	1.0	0.2	0.5	0.6	0.0	0.3	0.6	0.2	-0.9	0.5	0.0	0.0	0.7
28	1.0	1.3	1.2	0.1	1.1	1.4	-0.1	0.6	1.2	0.2	-0.4	0.2	0.0	0.0	0.8
29	-3.0	-3.1	-2.3	0.1	0.4	-0.8	-0.1	-0.1	-0.9	0.0	-1.0	-1.0	0.0	-0.3	-2.0
30	-1.2	-1.1	-0.4	0.1	1.3	0.0	-0.1	1.0	1.3	0.1	-0.6	0.5	0.0	-0.1	-0.5
31	1.3	1.4	1.2	0.1	1.0	0.5	-0.0	0.7	0.2	0.1	-0.1	0.1	0.0	0.0	0.7
32	1.1	1.4	1.3	0.1	1.6	1.1	-0.1	1.5	0.6	0.1	-0.4	-0.2	0.0	0.0	0.6
33	-2.9	-3.1	-2.4	0.0	0.4	-1.1	-0.1	-0.2	-1.0	0.0	-1.0	-1.1	0.1	-0.3	-2.1
34	-1.0	-1.0	-0.5	0.0	1.6	0.8	-0.1	1.4	1.3	0.1	-1.0	0.2	0.0	-0.1	-0.7
35	1.2	1.2	1.1	0.1	0.9	0.4	-0.0	0.4	0.0	0.1	-0.2	-0.2	0.0	0.1	0.7
36	1.0	1.3	1.0	0.0	1.8	1.7	-0.2	1.5	0.6	0.1	-0.2	-0.5	0.0	0.1	0.6
37	-0.9	-1.2	-0.8	-0.2	0.1	0.7	-0.1	-0.4	0.4	0.1	-0.1	-0.6	0.0	-0.1	-0.2
38	-0.2	1.1	1.2	0.1	-0.4	0.3	-0.4	-1.2	0.7	0.0	0.2	1.2	0.2	0.0	0.2
39	-0.6	1.8	-0.9	-0.6	3.3	-7.9	1.5	2.3	-3.4	0.7	-1.0	4.3	-0.0	-0.3	-1.8
*	1.4	2.4	1.3	0.8	3.3	1.4	1.5	2.3	1.4	0.7	0.4	4.3	0.6	0.2	1.9
	-3.0	-3.7	-2.8	-0.9	-1.4	-7.9	-0.8	-4.5	-3.4	-0.2	-1.1	-1.2	-0.4	-0.7	-2.6

Note : * the maximum positive errors and the maximum negative errors of each element

要素は 4% 以内で求まるとみなしてよい。

ここに、§3 で示した補間式に本節で示した補正を加えたものを基本 Flexibility Matrix F^* の実用算定式として提案する。この算定式のコンピュータープログラム例を以下に示す。Table 15 および Table 16 に F^* の要素の数値計算例をプログラムのチェック用として示す。

結 論

異なる対称な断面形状を有する耐震壁の基本 Flexibility Matrix F^* の要素の解析値 2,430 個を数表に掲げ、電算機に記憶させたこの解析値を使って、対称でしかも任意の実用的な断面形状を有する耐震壁の F^* の各要素をいずれも 5% 以内の誤差で求められる実用算定法とその電算プログラム、ならびにプログラムチェック用の F^* の数値計算例を示した。従って、この F^* から単独耐震壁の一般的な Stiffness Matrix $\bar{K}$ を十分な精度で容易に求められることになった¹⁾。

謝 辞

原稿の清書およびタイプをしていただいた九州大学研究補助員古田紀代子嬢に謝意を表します。

Table 14 The 21 combinations of the aspect ratios by which the errors of the interpolated element b_{13} of F^* are investigated

No.	α_a	α_b	β_a	β_b	A_a/A_b^*
1	0.3	0.1	6	2	9
2	0.25	0.1	6	2	7.5
3	0.2	"	"	"	6
4	0.15	"	"	"	4.5
5	0.1	"	"	"	3.
6	0.3	0.1	5	2	7.5
7	"	"	4	"	6
8	"	"	3	"	4.5
9	"	"	2	"	3
10	0.3	0.15	6	2	6
11	"	0.2	"	"	4.5
12	"	0.25	"	"	3.6
13	"	0.3	"	"	3
14	0.3	0.1	6	3	6
15	"	"	"	4	4.5
16	"	"	"	5	3.6
17	"	"	"	6	3
18	0.1	0.3	2	6	0.11
19	0.275	0.125	5.5	2.5	4.84
20	0.25	0.15	5	3	2.78
21	0.3	0.3	6	3	2

Note : * $A_a/A_b = \alpha_a\beta_a/\alpha_b\beta_b$

Fig. 13 The absolute error $|R|$ of each element b_{18} , derived by correcting its interpolated value, corresponding to various A_a/A_b (for $\lambda=1.5$)

```

C
  ** INTERPOLATION WITH REGARD TO THE VARIABLE ALPHA8 **
  J=PRST(3)-PRST(2)
  P=PRST(12)-PRST(1)
  G(M)=PRST(12)
  W=P*O*(U-2.0)
  IF(W.NE.3.0) G(M)=G(M)+2.0*W/((P-G)*U+3.0*Q-T)
70 CONTINUE

C
  ** INTERPOLATION WITH REGARD TO THE VARIABLE LAMBDA **
  FFM(1)=G(1)/2.0
  V1=(V1-3)/2.0
  FFM(2)=G(2)*V1*(G(3)-G(2))
  IF(V.GE.2.0) FFM(3)=G(5)*(G(6)/G(5))*((ALOG(V/2.0)/ALOG(1.5))
  FFM(4)=G(7)*V1*(G(8)-G(7))
  DO 80 N=5,12
  FFM(N)=G(2*N)
  FFM(13)=G(25)*V1*(G(26)-G(25))
  FFM(14)=G(27)*V1*(G(28)-G(27))
  FFM(15)=G(29)*V1*(G(30)-G(29))
  IF(V.GE.2.0) GJ TG 90
  V2=V-1.0
  V3=V2*(3.0-V)
  AA3YAB=ALPHA8+BETAA/ALPHA8/BETAB
  IF(LAMBDA.LT.1.0) AA3YAB=1.0/AA3YAB
  FFM(3)=G(4)*(G(5)/G(4))*((ALOG(V)/ALOG(2.0))
  FFM(6)=G(11)*V2*(G(12)-G(11))
  IF(V.GE.1.5) FFM(6)=FFM(6)/(1.0+(V-2.0)*(0.032+0.012*AA3YAB))
  FFM(9)=G(17)*V2*(G(18)-G(17))
  FFM(12)=G(23)*V2*(G(24)-G(23))
  FFM(7)=G(13)*V3*(G(14)-G(13))
  FFM(10)=G(19)*V2*(G(20)-G(19))
  IF(V.GE.1.75) GO TO 90
  V4=(1.75-V)/0.75)*2.5
  FFM(5)=G(10)*V4*(G(9)-G(10))
  IF(V.GE.1.5) GO TO 90
  V5=4*V2*(2.0-V)
  FFM(8)=G(15)*V5*(G(16)-G(15))
  FFM(11)=G(21)*V5*(G(22)-G(21))
  IF(V.LT.1.25) GO TO 85
  FFM(6)=FFM(6)/(0.924-0.006*AA3YAB+V/25.0)
  GO TO 90
  85 FFM(6)=FFM(6)/(1.0-(V-1.0)*(0.104+0.024*AA3YAB)).
  90 IF(LAMBDA.GE.1.0) GO TO 100

C
  ** PERMUTATION WHEN 0.3333 <= LAMBDA < 1.0 **
  OFFM=FFM(1)
  FFM(1)=FFM(3)
  FFM(3)=OFFM
  OFFM=FFM(4)
  FFM(4)=FFM(7)
  FFM(7)=OFFM
  OFFM=-FFM(6)/LAMBDA
  FFM(6)=-FFM(8)/LAMBDA
  FFM(8)=OFFM
  FFM(9)=FFM(9)/LAMBDA**2
  OFFM=FFM(10)
  FFM(10)=FFM(13)
  FFM(13)=OFFM
  OFFM=-FFM(11)/LAMBDA
  FFM(11)=-FFM(14)/LAMBDA
  FFM(14)=OFFM
  OFFM=FFM(12)/LAMBDA**2
  FFM(12)=FFM(15)/LAMBDA**2
  FFM(15)=OFFM

C
  100 WRITE(6,3000) LAMBDA,ALPHA8,ALPHA8,BETAA,BETAB,FFM
  3000 FORMAT(1H0,10X,' *** LAMBDA=',F10.3,' ALPHA8=',F10.3,' ALPHA8=
  1 F10.3,' BETAA=',F10.3,' BETAB=',F10.3,' *** ',
  2 /1H0,20X,1P9E12.3)
  GO TO 10
9999 STOP
END

```


Table 15 Numerical examples of the practical values and analytical values of the elements of F^* (see Eq. 1), where $\lambda=2.75$, $\alpha_a=0.1714$, $\alpha_b=0.1714$, $\beta_a=2.5$, $\beta_b=3.333$

X_I^*	Y_I^*	X_{II}^*	Y_{II}^*	M_{II}^*/h	Y_{III}^*	M_{III}^*/h	X_{IV}^*	M_{IV}^*/h
5.509 (5.520)	-3.256 (-3.216)		0					
	3.156 (3.120)							
		0.5413 (0.5409)	-0.08607 (-0.08645)	1.542 (1.537)				
			0.5632 (0.5657)	-1.034 (-1.015)		0		
				28.78 (28.59)				
					0.6530 (0.6530)	-1.850 (-1.847)		
						27.77 (27.45)	0	
							0.5735 (0.5722)	1.568 (1.568)
								26.64 (26.60)

Note: The analytical values are put in parenthesis.

Table 16 Numerical examples of the practical values and analytical values of the elements of F^* (see Eq. 1), where $\lambda=0.75$, $\alpha_a=0.1714$, $\alpha_b=0.1714$, $\beta_a=2.5$, $\beta_b=3.333$

X_I^*	Y_I^*	X_{II}^*	Y_{II}^*	M_{II}^*/h	Y_{III}^*	M_{III}^*/h	X_{IV}^*	M_{IV}^*/h
5.545 (5.591)	-13.30 (-13.42)		0					
	40.96 (41.15)							
		1.604 (1.603)	-0.1452 (-0.1444)	1.608 (1.613)				
			0.6038 (0.6041)	-1.439 (-1.435)		0		
				28.31 (28.28)				
					0.6044 (0.6038)	-1.421 (-1.432)		
						28.24 (28.30)	0	
							2.231 (2.231)	4.870 (4.877)
								32.83 (32.93)

Note: The analytical values are put in parenthesis.

付 記

数値計算には九州大学大型計算機センターの FACOM 230-75 および九州大学中央計数施設の FACOM 230-45 S を使用した。

本研究は昭和 50~52 年度文部省科学研究費補助金の援助を受けた。

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PRACTICAL CALCULATION METHOD OF THE STIFFNESS MATRIX OF FRAMED SHEAR WALLS PART II

—Practical Calculation Method of Fundamental Flexibility Matrix—

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PREFACE

As the pages are limited, this paper is separated into two parts, and

Part I : Characteristics of the Elements of Fundamental Flexibility Matrices and Fundamental Stiffness Matrices was reported in the previous Transactions No. 278 published in April 1979.

The purpose of this paper was described in §1 Introduction in Part I.

§3 Interpolation Formulae of the Elements of Fundamental Flexibility Matrix

All the elements of stiffness matrix $\bar{K}$ and fundamental flexibility matrix F^* can be expressed in nondimensional form by removing the common factor expressed in the Young's modulus E , the story height h and the thickness t of the wall (see Eqs. 1 and 3 in Part I), and the nondimensional elements are dependent on the five aspect ratios λ , α_a , α_b , β_a and β_b of the shear wall only²⁾ (see §1 and Fig. 2 in Part I).

By the successive interpolation with regard to each aspect ratio, the elements of F^* of a given shear wall can be derived from the prepared analytical values of the elements of basic shear walls.

Considering the effects of the variations of the aspect ratios upon the elements of F^* (see §2 in Part I), all the elements are given by the hyperbolic interpolation formulae for the variables α_a , α_b , β_a and β_b , and by the appropriate interpolation formulae corresponding to the ranges of the variable λ (see Table 7).

In order to begin the interpolation with a more accurate interpolation formula, the order of the variables applied to the interpolation is adopted as follows (see Tables 3 and 4 in Part I).

$$\beta_a \rightarrow \beta_b \rightarrow \alpha_a \rightarrow \alpha_b \rightarrow \lambda$$

The interpolated value $f(x)$ of the element of F^* can be expressed in the variable x which is one of aspect ratios α_a , α_b , β_a and β_b and three known values $f(x_1)$, $f(x_2)$ and $f(x_3)$ of the element corresponding to the maximum, intermediate and minimum values x_1 , x_2 , x_3 of the aspect ratios mentioned in the beginning of §2 (see Fig. 9), and the interpolation formula is given by Eq. 9, where the other aspect ratios including span-height ratio λ are fixed.

The interpolation formulae whose variable is λ are shown in Table 7, where the other aspect ratios are fixed. When λ of the given shear wall is in the hatched range, the known values of the element corresponding to the minimum and maximum values of the hatched range of λ must be substituted in the formula together with λ of the given shear wall, but when λ of the given shear wall is in the blank range, the element is constant and takes the value corresponding to the proper λ in the blank range without interpolation.

Hence 30 known elements of F^* are necessary to calculate all the elements of F^* of the given shear wall whose λ is in the range 1~3.

When it is taken into consideration that three known values are necessary for one hyperbolic interpolation, in order to repeat the hyperbolic interpolations with regard to four aspect ratios α_a , α_b , β_a and β_b , the analytical values of the elements of F^* related to the 81 combinations of $\alpha_a=0.1, 0.2, 0.3$,

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$\alpha_b=0.1, 0.2, 0.3, \beta_a=2, 4, 6, \beta_b=2, 4, 6$ must be prepared.

Therefore, in order to calculate all the elements of F^* of the shear walls whose λ is in the range 1~3, the 2430 ($=30 \times 81$) analytical values of the elements must be prepared, and these values are shown in Tables 8~10. For example, the notation "2.373-2" means the value 2.373×10^{-2} .

In the case of $1/3 < \lambda < 1$, the elements of F^* of the given shear wall whose other aspect ratios are $\alpha_a, \alpha_b, \beta_a$ and β_b can be given by permuting the beams and columns for the columns and beams of the permuted shear wall whose span-height ratio λ' is equal to $1/\lambda$ (see Fig. 3 in Part I). Thus, the aspect ratios $\lambda', \alpha_a', \alpha_b', \beta_a'$ and β_b' of the permuted shear wall are defined as follows.

$$\lambda' = \frac{1}{\lambda}, \quad \alpha_a' = \frac{\alpha_b}{\lambda}, \quad \alpha_b' = \frac{\alpha_a}{\lambda}, \quad \beta_a' = \beta_b, \quad \beta_b' = \beta_a$$

The relations between the elements of F^* of a given shear wall and those of the permuted shear wall are mentioned in Table 11, where the symbols defined by $|\lambda'$ express the elements of F^* of the permuted shear wall.

§4 Accuracy of the Elements Derived by Successive Interpolations

4.1 Shear Walls Adopted for This Investigation

The 39 different shaped shear walls are adopted for the investigation of the errors between the elements of F^* given by the interpolation formulae and those given analytically, where their aspect ratios are shown in Table 12 together with the values of l, D_a and D_b corresponding to an example $h=350$ cm and the values B_a and B_b corresponding to an example $t=18$ cm for reference.

The 12 kinds of shapes of the cross sections of the beams and columns of the shear walls Nos. 1~36 are defined so as to have all the combinations of the values near the maximum and minimum dimensions of their depths and widths in practice. For these 12 combinations the three span-height ratios $\lambda=0.75$ (No. 1~No. 12), $\lambda=1.25$ (No. 13~No. 24) and $\lambda=2.75$ (No. 25~No. 36) are considered.

The proportion of the shear wall No. 37 is general and is equal to that of the shear wall applied to the design example in the Commentary of A.I.J. (Architectural Institute of Japan) Building Code Requirements for Reinforced Concrete, and $\alpha_a, \alpha_b, \beta_a$ and β_b of the shear wall No. 38 are equal to those of the shear wall No. 37, but λ of the shear wall No. 38 is 0.75. The shear wall No. 39 has the proportion which induces a large error of the element b_{13} of F^* (see Table 5 in Part I).

The shear walls Nos. 1~38 are the examples whose elements include accumulative errors by the successive interpolations with regard to all the five aspect ratios, and the shear wall No. 39 is an example whose elements include large errors by the interpolation with regard to λ only.

4.2 Investigation of the Accumulative Errors

The accumulative errors between the successively interpolated values and analytical values of the elements of F^* of the 39 shear walls shown in Table 12 are mentioned in Table 13, and the following results are made clear.

The accumulative errors of all the elements of F^* of the shear walls are less than 5%, except for the error of the element b_{13} of the shear wall No. 39 which is 7.9% (see Table 13). But the interpolation formula of b_{13} (b_{23}) with regard to the valuable λ which is in the range 1~2 ($1/2 \sim 1$) (see Table 7) induces large errors up to 8% as mentioned in Table 5 in Part I, when sectional areas of the beams (columns) are remarkably larger than those of the columns (beams).

§5 Practical Calculation Method of Fundamental Flexibility Matrix by Correcting Its Elements Derived by Interpolation

The correction of the interpolated elements b_{13} (b_{23}) of various F^* is investigated by using the interpolated values of the 21 shear walls whose aspect ratios $\alpha_a, \alpha_b, \beta_a$ and β_b together with the ratio A_a/A_b ($=\alpha_a\beta_a/\alpha_b\beta_b$) of the sectional area A_a of the beams to that A_b of the columns are mentioned in Table 14 and whose λ is taken as 1, 1.25, 1.5, 1.75 and 2.

When $\lambda=1$ or 2, the errors of b_{13} of all the shear walls are less than 2%, but if $\lambda=1.25$ or 1.5, the errors of b_{13} of some of the shear walls are more than 5% in negative side.

When $\lambda=1.25$ and 1.5 , the absolute error $|R|$ of each b_{13} corresponding to the ratio A_a/A_b is shown in Figs. 10 and 11, where the maximum absolute error of each of the other elements of F^* mentioned in Table 13 is shown together for comparison. If the relation between the average of $|R|$ and A_a/A_b is assumed to be expressed in straight line, the relations for $\lambda=1.25$ and 1.5 can be expressed in Eqs. 11 and 12, where $|R|_{ave}$ is expressed in $\%$. The relations given by Eqs. 11 and 12 are also shown in Figs. 10 and 11. When it is taken into consideration that the errors are negative in general or less than about 1% if positive, the large negative errors decrease if b_{13} is given by the correction formula $f(\lambda) \times (1+|R|_{ave}/100)$ where $f(\lambda)$ is the interpolation formula (see Table 7), because the center of the range of the errors of all the shear walls approaches to zero. In consequence the errors of all the shear walls become less than 4% as mentioned in Figs. 12 and 13.

When λ is in the ranges $1 \sim 1.25$, $1.25 \sim 1.5$ and $1.5 \sim 2.0$, b_{13} is given respectively by Eqs. 13, 14 and 15 which are the linear interpolation formulae, where it is assumed that when λ is equal to 1 or 2 the correction is not necessary.

As the element b_{23} for $1/2 \leq \lambda < 1$ is given as b_{13} of the permuted shear wall whose span-height ratio λ' is equal to $1/\lambda$, the error of b_{23} can be corrected too.

Thus, all the elements of F^* whose errors are less than 5% can be derived for any aspect ratios satisfying $1/3 \leq \lambda \leq 3$, $0.1 \leq \alpha_a \leq 0.3$, $0.1 \leq \alpha_b \leq 0.3$, $2 \leq \beta_a \leq 6$ and $2 \leq \beta_b \leq 6$. If it is taken into consideration that A_a/A_b is usually in the range $1/4 \sim 4$, the errors are less than 4% in general.

This calculation method is proposed as practical calculation method of the elements of the fundamental flexibility matrix F^* by whose terms the elements of the stiffness matrix $\bar{K}$ of the shear wall are expressed in (see Table 1 in Part I).

An example of the computer program of the practical calculation method and two numerical examples to check the program are shown (see Tables 15 and 16).

CONCLUSION

The practical calculation method of the elements of the fundamental flexibility matrices of symmetric elastic framed shear walls whose errors are less than 5% is proposed, and its computer program, the numerical tables of the 2430 analytical values of the elements to be memorized and two numerical examples for checking the program are mentioned.

The first step of the method is to derive the elements by successive interpolation with regard to each aspect ratio, and the final step is to correct the element b_{13} for $1 \leq \lambda \leq 2$ or the element b_{23} for $1/2 \leq \lambda \leq 1$ with regard to λ and A_a/A_b , where λ is span-height ratio and, A_a and A_b are the sectional areas of the beams and columns.

Thus, the stiffness matrix $\bar{K}$ of the shear walls whose elements are expressed in terms of the elements of the fundamental flexibility matrix F^* can be calculated practically (see Table 1 in Part I).

ACKNOWLEDGEMENT

The authors wish to thank Miss Kiyoko Furuta who typed the manuscript of this paper.

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