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**COLLOQUIUM on:  
"INTERFACE BETWEEN COMPUTING AND DESIGN IN STRUCTURAL ENGINEERING"**

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**Computer Aided Design of Bridges Using STRAINS and KABE Systems**

Project des ponts à l'aide de l'ordinateur et des systèmes STRAINS et KABE

Mit den Systemen STRAINS und KABE hilft Computer beim Brückenprojektieren

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**Summary**

The applications of two systems to facilitate the design of prestressed concrete bridges are presented. Examples of applications of STRAINS, a structural analysis system - to calculate the internal forces and KABE, a prestressed concrete design system - to determine the cable trajectories and the prestressing force are discussed. The examples of printer output and three colour BENSON drawings are given.

**Résumé**

On présente l'application de deux systèmes STRAINS et KABE qui facilitent l'établissement des projets de ponts en béton précontraint.

STRAINS : pour le calcul statique, KABE : pour la détermination des forces de précontrainte et de la position des câbles. Quelques exemples de sorties numériques et graphiques - trois dessins faits sur la table autotraçante BENSON sont présentés.

**Zusammenfassung**

Es werden zwei Systeme vorgestellt, die das Projektieren von Spannbetonbrücken erleichtern. Anwendungsbeispiele von STRAINS, einem Programm zur Berechnung der Schnittkräfte, und KABE, einem System zur Bestimmung von Kabellagen und Spannkraften werden behandelt. Beispiele der numerischen und der mehrfarbigen graphischen Ausgabe werden gezeigt.

## 1. INTRODUCTION

STRAINS /Structural Analysis Integrated System/ is a package of automatically operated programs for the analysis of the internal forces and displacements in the skeletal, surface or massive elastic structures. It was developed in 1970-75 with the aim to assure widest acceptance and good maintenance over a long period of time. It has two versions: STRAINS 71 and STRAINS 75. They differ by the scope of the problems which can be solved and by the hardware required to operate the system. [1], [2], [5] .

KABE is a computer system for the design of prestressed bridges. It is available in two versions: KABE 73 and KABE 76. The difference between the versions is that the 76 version is equipped with the devices to facilitate data preparation. [3] , [4], [6]. Both systems operate on ODRA 1300 series computers which are an equivalent of ICL 1900 series and are running under the ICL operating systems. To run STRAINS 71, KABE 73 or KABE 76 a 32k word core memory is required and 4 to 6 Magnetic Tape units, but not the random access memory. STRAINS 75 requires access to disc memory. Both systems operate in batch mode: they are simple yet effective, user-oriented and friendly.

## 2. CHARACTERISTICS AND FUNCTION OF THE SYSTEMS

### 2.1 General characteristics of both systems.

Both systems were intended for use in the Design Offices as well as in Civil Engineering Faculties: they had therefore to deal efficiently both with large and small size problems. Both of them have user-oriented languages.

### 2.2 STRAINS

The system is intended for the calculation of internal forces and displacements in trusses, frames /both plane or space/, grillages, plates, plates in bending, shells, solid three dimensional structures and structures composed of bars and shell

elements. It can deal efficiently both with large and small size problems of analysis, leaving out only the not so often encountered problems of more than 6000 Degrees of Freedom to be computed using other systems of analysis.

STRAINS is not only user oriented but is also very friendly. The command GENERATING causes an incremental method of data generating to be used.

In the extreme case of the regular, straight line grids, the entire data needed for the node numbering and the definition of nodal coordinates can be given in just three lines for any plane structure and in four lines-for a space structure.

Similar generator can be applied to the description of the topology.

In the case of more complicated, but regular grids the user can either devise his own data generating program or use data prepared independently and input it via the magnetic or paper tape, using the command EXTRA INPUT.

The problem-oriented language compiler checks the input data for errors and in the cases they occur, a message is output. Geometrical and topological errors can be spotted at a glance in a picture output on the line printer. The errors can be corrected by writing just a few lines.

The data can be easily modified, changed, added or deleted in subsequent computer runs.

In fact, this is the nearest one could get to the interactive mode, without actually having the necessary hardware.

The form of the printouts /both formats and tables/ is automatically adjusted.

When the user wants to limit the amount of printouts, he can specify the required results.

The scale of the line printer sketch as well as the scales of the plotter drawings are automatically adjusted, so that only one command DRAW is needed.

In the rare cases only when the drawing output is expected to be / or found to be / unsatisfactory, the user can give his own specifications concerning the scale and - in the case of space structures - the viewing angle.

The graphical output received special attention.

In the case of Finite Element Analysis, a map of stresses can be produced on the line printer.

Owing to the fact, that not all computer users have direct access to the plotters and also to save computer time, the graphical output of STRAINS is registered on a Magnetic Tape and processed off-line on a plotter /in our case it is a BENSON 122 drum plotter/.

A two-level program structure has been devised, however, to make the graphical output device - independent.

Some examples of the graphical output available are shown in the examples.

At the moment STRAINS-75 is operational on ODRA 1300 series, ICL 1900 and 2900 series computers. In particular, it runs very well under George 2 and George 3 operating systems, and on ICL 2903 mini, although in this last case the computing times are fairly slow owing to the 1900 emulator.

STRAINS-75 is installed in some 11 out of the 15 Civil Engineering Faculties in Poland and in about 15 other computing centres, serving regularly some 30 Design Offices and occasionally further 40 or 50.

### 2.3. KABE

The other system developed at the Institute for Highway and Bridge Design, is KABE-76 - a system for the preliminary design of the prestressed concrete bridges.

The statical scheme of the bridge is a multi-span beam.

It may have varying cross section along the span.

The system can cope with any shape of cross-section as long as it can be described using less than a 100 points with straightline connections between them.

Each span is automatically divided into 10 equal parts: all 10 cross sections at these points can be different from each other. The dead loads include self weight, continuous load along the entire span /due, for instance to road surface or track ballast/ and point loads /due to pipe hangers/.

The moving loads include the standard road - rail - or tramway loading as well as "special loading", consisting of up to 30 point loads of arbitrary magnitude and spacing.

The results at each of the 10 points along every span include:

- cross section properties
- envelope lines for Bending Moments, Shear Forces and support reactions for each type of the moving load
- maxima and minima for the combinations of loads
- parameters of the permissible cable zone
- prestressing cable trajectory
- extreme values of the prestressing forces
- stresses in top and bottom fibres
- quantities of the prestressing steel and concrete for each of the four values of the prestressing force.

The system is composed of a problem-oriented language compiler and 9 programs, of which one provides the graphical output.

In the initial stages, system KABE was very much different from STRAINS and had no problem-oriented language.

The experience gained during the several years of using both systems brought KABE more into line with STRAINS as far as user-system interface is concerned. From the point of view of hardware, KABE is similar to STRAINS in that it is operational on ODRA 1300 and ICL 1900 and 2900 series and runs well under GEORGE 2 and GEORGE 3 operating system.

32 K words core capacity only is required.

The latest development of KABE is its inclusion in a large system for checking the strength of the existing bridges under extra-ordinary loading. KABE is used to compare, point-by-point, the Bending Moment and Shear Force envelopes under the standard and under the special loading. In case the values of special loading envelopes exceed those of standard loading, the warning is output and the bridge is considered unsafe for that particular special load.

### 3. EXAMPLES OF APPLICATION

#### 3.1 STRAINS

##### 3.1.1 The analysis of the internal forces in a space frame bridge.

A space frame bridge in which some nodes are pin-jointed was analysed. The structure consists of 143 joints and 296 bars. The fragments of the program are shown in Table 1. The printer sketch is shown in Fig. 1

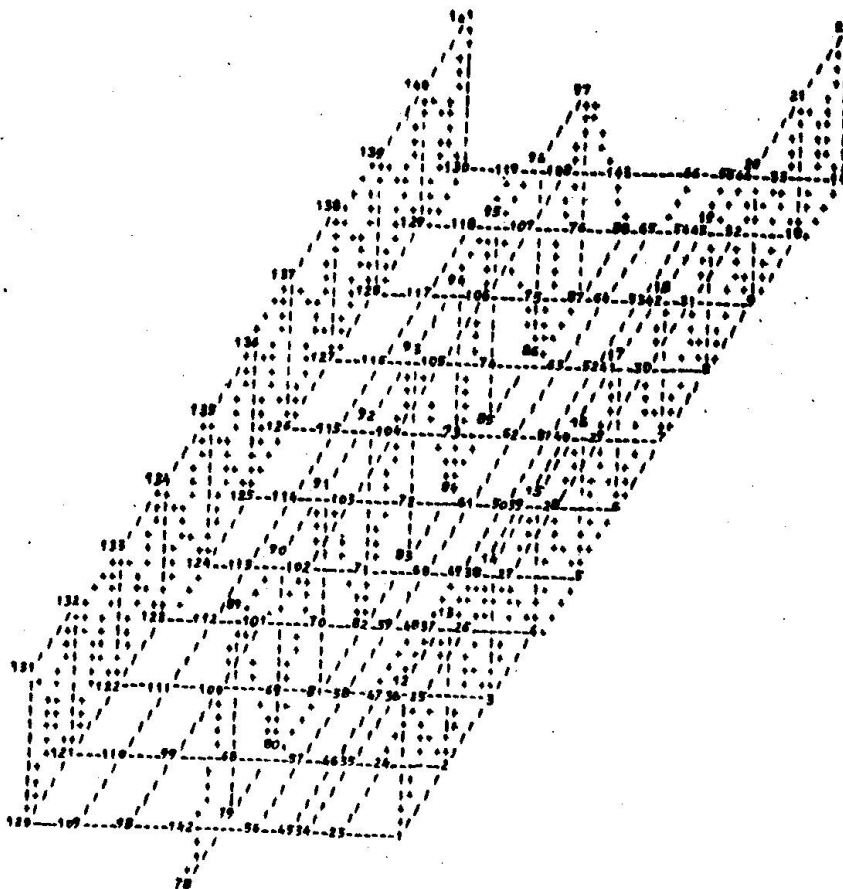


Fig. 1. The printer sketch of a large steel bridge frame.

```

1  'STRUCTURE' MOST T-2
2  'TYPE' 'SPACE FRAME'
3  'JOINTS' 143
4  'ELEMENTS' 296
5  'STIFFNESS METHOD'
6  'GEOMETRICAL DATA'
7  'JOINT COORDINATES'
8  1,1120,0,0,
9  2,1120,361,0,
10 3,1120,722,0,

151 'SYSTEM OF ELEMENTS'
152 1,1,2,
153 2,2,3,

447 296,117,128,
448 'PROPERTIES'
449 'ELEMENTS' 'E' 'V' 'ALPHA'
450 'ALL' 2100000,0,3,0,
451 'ELEMENTS' 'A' 'IV' 'IZ' 'IX'
452 4,41,42,191,210,98,8,11889,22691,56,

487 9,121,122,123,124,125,126,127,128,129,222.4,46803,47541,420,
488 'ALLREST' 303,2,568930,5711,765,
489 'BOUNDARY CONDITIONS'
490 1,120,'FIXED IN' 'Y' 'Z'
491 78,142,'FIXED IN' 'X' 'Y' 'Z'

494 'LOAD DATA'
495 'JOINT LOAD'
496 1,11,'Z',1875,
497 2,10,'Z',2860,

642 106,119,'Z',7220,
643 33,44,55,66,'Z',3610,
644 'GEOMETRICAL OUTPUT'
645 'JOINT ROTATIONS'
646 'JOINT DISPLACEMENTS'
647 'INTERNAL FORCES'
648 'SOLVE'
649 'END'

```

Table 1. A fragment of STRAINS program.

3.1.2 The analysis of the internal forces in the web of a pre-stressed concrete beam.

A diafragm of a box section highway bridge was analysed. Out of a complete set of the results consisting of printouts, printer graphics and the graphical output, drawing obtained on BENSON 122 graph plotter are shown in Fig. 2, 3 and 4.



### 3.1.3 Analysis of a plate in bending type of viaduct

A plate in bending viaduct was analysed. A printer scatch of stress distribution is shown on Fig.5.

## 3.2 KABE

### 3.2.1 An analysis of a prestressed concrete highway bridge.

An analysis is carried out of the internal forces under the Polish Standard Road Loading and calculation of the excentricity and the prestressing force.

Fragment of program is shown on Table 2. The results are output on the printer and graphplotter.

The drawings of the beam cross section influence lines of bending moment and the cable trajectory are presented in three colours as the graphical output /Fig.6,7,8/.

UNLOAD ELEMENTUM

1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32
33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48
49	50	51	52	53	54	55	56
57	58	59	60	61	62	63	64
65	66	67	68	69	70	71	72
73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88
89	90	91	92	93	94	95	96
97	98	99	100	101	102	103	104
105	106	107	108	109	110	111	112
113	114	115	116	117	118	119	120
121	122	123	124	125	126	127	128
129	130	131	132	133	134	135	136
137	138	139	140	141	142	143	144
145	146	147	148	149	150	151	152
153	154	155	156	157	158	159	160
161	162	163	164	165	166	167	168
169	170	171	172	173	174	175	176
177	178	179	180	181	182	183	184
185	186	187	188	189	190	191	192
193	194	195	196	197	198	199	200
201	202	203	204	205	206	207	208
209	210	211	212	213	214	215	216
217	218	219	220	221	222	223	224
225	226	227	228	229	230	231	232
233	234	235	236	237	238	239	240
241	242	243	244	245	246	247	248
249	250	251	252	253	254	255	256
257	258	259	260	261	262	263	264
265	266	267	268	269	270	271	272
273	274	275	276	277	278	279	280
281	282	283	284	285	286	287	288
289	290	291	292	293	294	295	296
297	298	299	300	301	302	303	304
305	306	307	308	309	310	311	312
313	314	315	316	317	318	319	320
321	322	323	324	325	326	327	328
329	330	331	332	333	334	335	336
337	338	339	340	341	342	343	344
345	346	347	348	349	350	351	352
353	354	355	356	357	358	359	360
361	362	363	364	365	366	367	368
369	370	371	372	373	374	375	376
377	378	379	380	381	382	383	384
385	386	387	388	389	390	391	392
393	394	395	396	397	398	399	400
401	402	403	404	405	406	407	408
409	410	411	412	413	414	415	416
417	418	419	420	421	422	423	424
425	426	427	428	429	430	431	432
433	434	435	436	437	438	439	440
441	442	443	444	445	446	447	448
449	450	451	452	453	454	455	456
457	458	459	460	461	462	463	464
465	466	467	468	469	470	471	472
473	474	475	476	477	478	479	480
481	482	483	484	485	486	487	488
489	490	491	492	493	494	495	496
497	498	499	500	501	502	503	504
505	506	507	508	509	510	511	512
513	514	515	516	517	518	519	520
521	522	523	524	525	526	527	528
529	530	531	532	533	534	535	536
537	538	539	540	541	542	543	544
545	546	547	548	549	550	551	552
553	554	555	556	557	558	559	560
561	562	563	564	565	566	567	568
569	570	571	572	573	574	575	576
577	578	579	580	581	582	583	584
585	586	587	588	589	590	591	592
593	594	595	596	597	598	599	600
601	602	603	604	605	606	607	608
609	610	611	612	613	614	615	616
617	618	619	620	621	622	623	624
625	626	627	628	629	630	631	632
633	634	635	636	637	638	639	640
641	642	643	644	645	646	647	648
649	650	651	652	653	654	655	656
657	658	659	660	661	662	663	664
665	666	667	668	669	670	671	672
673	674	675	676	677	678	679	680
681	682	683	684	685	686	687	688
689	690	691	692	693	694	695	696
697	698	699	700	701	702	703	704
705	706	707	708	709	710	711	712
713	714	715	716	717	718	719	720
721	722	723	724	725	726	727	728
729	730	731	732	733	734	735	736
737	738	739	740	741	742	743	744
745	746	747	748	749	750	751	752
753	754	755	756	757	758	759	760
761	762	763	764	765	766	767	768
769	770	771	772	773	774	775	776
777	778	779	780	781	782	783	784
785	786	787	788	789	790	791	792
793	794	795	796	797	798	799	800
801	802	803	804	805	806	807	808
809	810	811	812	813	814	815	816
817	818	819	820	821	822	823	824
825	826	827	828	829	830	831	832
833	834	835	836	837	838	839	840
841	842	843	844	845	846	847	848
849	850	851	852	853	854	855	856
857	858	859	860	861	862	863	864
865	866	867	868	869	870	871	872
873	874	875	876	877	878	879	880
881	882	883	884	885	886	887	888
889	890	891	892	893	894	895	896
897	898	899	900	901	902	903	904
905	906	907	908	909	910	911	912
913	914	915	916	917	918	919	920
921	922	923	924	925	926	927	928
929	930	931	932	933	934	935	936
937	938	939	940	941	942	943	944
945	946	947	948	949	950	951	952
953	954	955	956	957	958	959	960
961	962	963	964	965	966	967	968
969	970	971	972	973	974	975	976
977	978	979	980	981	982	983	984
985	986	987	988	989	990	991	992
993	994	995	996	997	998	999	1000

Fig.2. Division into finite elem.

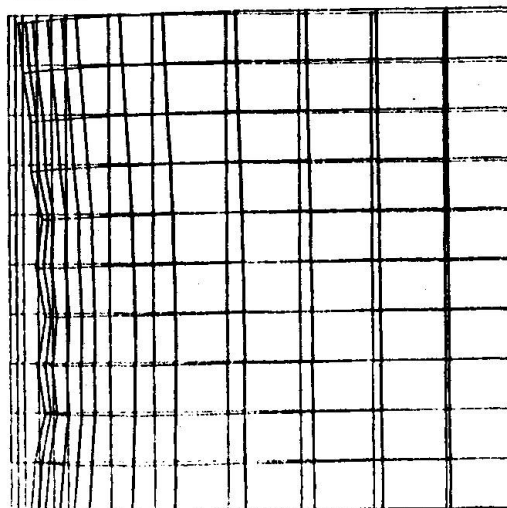


Fig.3. Deformation of the web

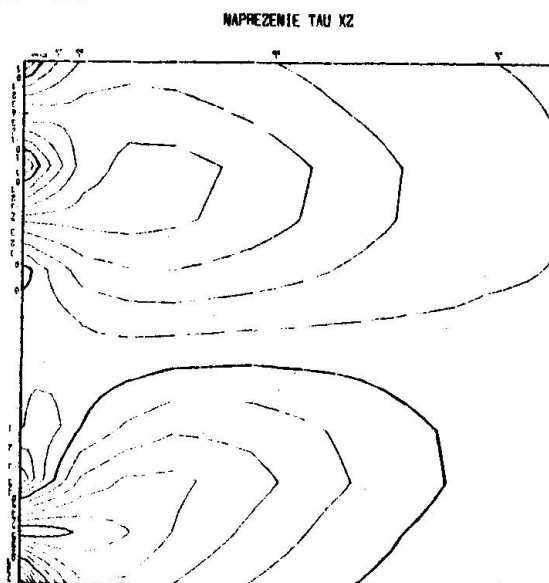


Fig.4. TAU XZ stress distribution

### 3.2.2 An analysis of a prestressed concrete railroad bridge

An analysis of internal forces under Polish Standard Railroad Loading and calculation of the excentricity and the prestressing force is carried out. The results are output on the printer and graph plotter. The printer sketch of the beam cross section is show on Fig. 9.

```

1      TRANSLATOR JEZYKA *KABE* IDIM PW      DATA:06/06/78
2      *MOST DROGOWY,PRZYKLAD NR 1,PRZEKROJ SKRZYNKOWY,
3      *LICZBA PRZESEL 3
4      *DANE GEOMETRYCZNE
5      *ROZPIETOSCI 56 70 56
6      PRZEKROJE POPRZECZNE
7      *PARAMETRY PRZEKROJU 1
8      LICZBA WEZLOW 21
9      *WSPOLRZEDNE NR X Y
10     1 0 0
11     2 13,5 0
12     *CIAGLE 2,52,2
13     *CIAGNIK D
14     *KROK ITERACJI 0.5
15     *OBCIAZENIA NIERUCHOME
16     *PRZESLOWE CIAGLE
17     *WSZYSTKIE PRZESLA 3.0
18     *WYNIKI
19     *SPREZENIE
20     *OTULINA DOLNA 0.15
21     *OTULINA GORNA 0.2
22     *KONIEC

```

Table 2. A fragment of KABE program.

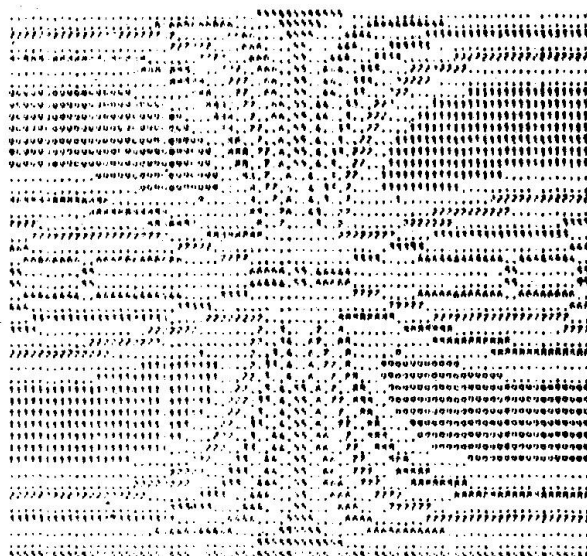


Fig.5 A printer sketch of  
TXY stress distribution

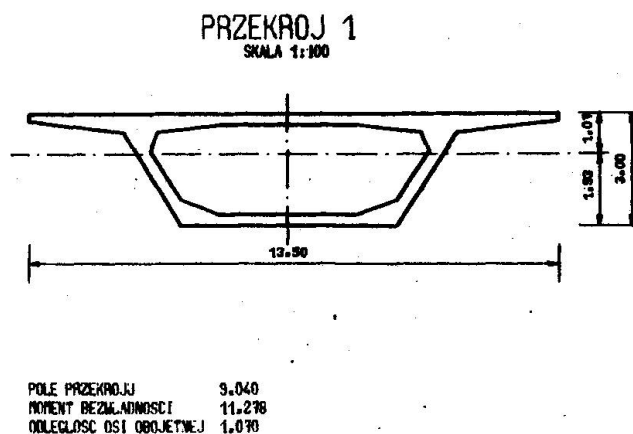
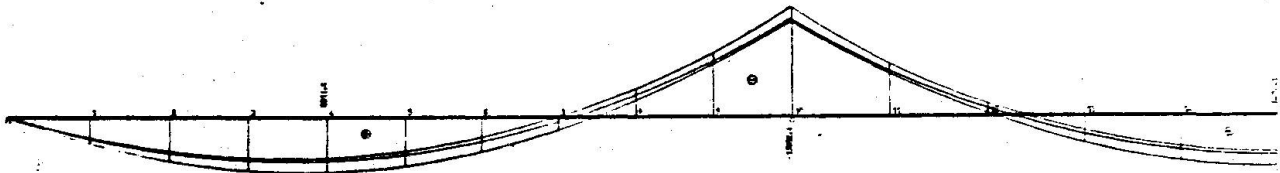
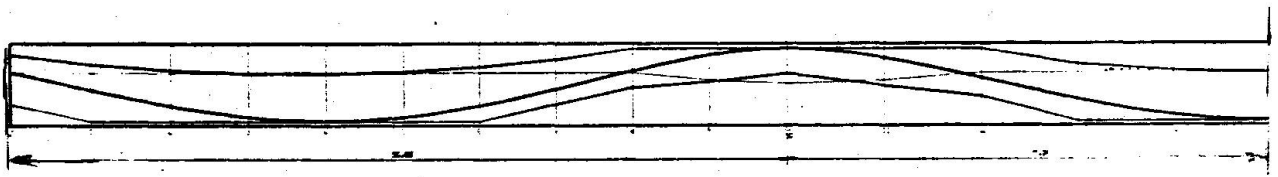


Fig.6 A drawing of the beam  
cross section

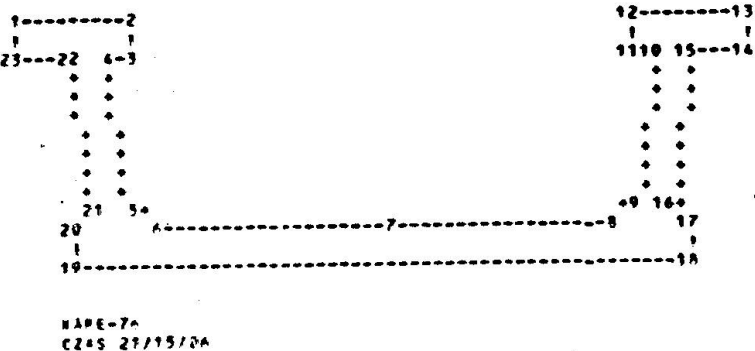
OBWIEDNIA MOMENTOW ZGINAJACYCH

Fig. 7. A bending moment diagram.OBWIEDNIA ROZENI UOGOLNIONYCH  
WYPADKOWA TRASA KABLI SPREZAJACYCHFig. 8. A cable trajectory in prestressed beam.

#### 4. CONCLUSIONS

Both systems, STRAINS and KABE afford a very good interface between designer and computer. They are suitable to the medium size computers. Thanks to the problem-oriented languages they are friendly and easy in application.

PRZESKROJ 1  
SKALA RYSUNKU 1: 40.00

Fig. 9. A printer sketch of the beam cross section.

Thanks to the two parallel language versions they may be used in other countries where, instead of the Polish language, other language versions could be used.

Thanks to the printer sketches and three-colour plotter output, the results produced by both systems are very easy to grasp and any mistakes can be easily located.

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