December 1994 Report No. UMCEE 94-38

Summary Report on
Semi-Active Base Isolation Control

by

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A report on research sponsored by

National Science Foundation

Grant No.NSF-BCS-9201787

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Acknowledgement

This work was supported by a grant from the National Science Foundation under Award No. BCS-9201787 as part of the Coordinated USA Research Program on Structural Control for Safety, Performance, and Hazard Mitigation. Any opinions, findings, and conclusions or recommendations expressed in this report are those of the author and do not necessarily reflect the views of the National Science Foundation.

Introduction

Isolating structures from ground motions is gaining popular acceptance as a technique for protecting structures from earthquake hazards (NEHRP, 1994). In essence, base isolation systems decouple the structure from the seismic disturbance, and reduce the energy transmission from the ground to the structure and from the structure to the ground.

Because passive base isolation systems limit the transfer of energy leaving the structure as well as the transfer of energy entering the structure, it has been proposed that the structural response can be improved by adjusting the isolator's properties based upon the instantaneous direction of energy transfer (Hanson and Firmansjah, 1992).

The direction of energy transfer is the same sign as the product of the ground velocity (*GV*) and the base shear (*BS*). To minimize the energy transferred to the structure, the properties of the isolation interface can be adjusted to minimize the forces in the isolation interface whenever energy being transferred to the structure. Therefore, one rule for controlling the isolator's properties is to specify maximum stiffness or damping when $(GV*BS) > 0$ and to specify minimum stiffness or damping otherwise. Because the system is non-linear and that the excitation is random, digital simulation are used to evaluate these control rules in this report.

Two other control rules are also investigated in this study. These two control rules replace $(GV*BS)$ in the first control rule by $(V*BS)$ and $(V*U)$, where (V) is the (relative) velocity of the structure with respect to the ground, and (U) is the deformation of the isolator. These control rules are of practical interest because (U) and (V) are relative quantities and are easier to measure than absolute ground velocity.

Because the compliance in a base-isolated structure is concentrated at the isolation interface, a base isolated structure is modeled as a SDOF oscillator in this study. The stiffness and damping properties of the SDOF model is that of the isolation system.

The main purpose of this study is to investigate how four peak response parameters (base shear (*BS*), relative displacement (*U*), energy input (*EI*), and total kinetic and potential energy (*EKS*)) are influenced by modulating the stiffness or damping properties of the isolation interface.

This report summarizes semi-active control computer simulation results of a single degree of freedom system subjected to the El Centro earthquake record. The candidate control algorithms are based on the sign of 1) Base Shear (*BS*) times Ground Velocity (*GV*); 2) Base Shear (*BS*) times Relative Velocity (*V*); and 3) Relative Velocity (*V*) times Relative Displacement (*U*). The products (*BS*)(*GV*), (*BS*)(*V*), and (*V*)(*U*) are referred to as "control parameters" in this report.

The report is divided into two main sections. The section I examines the effectiveness of specifying the damping rate as a function of the sign of a chosen control parameter. Section II examines the result of specifying the stiffness as a function of the sign of the control parameter.

Section I Semi-Active Damping Control

The damping control cases are summarized in Table 1. This table indicates the level of the damping specified when the control parameter is positive and negative. Note that Cases 1 and 2 are similar except that the "polarity" of the control rule is reversed (as are Cases 3 and 4). The entry "0 - 200 %" indicates that several levels of damping were considered in this specified range.

Table 1: Variable Damping Test Cases

Case	Sign of Control Parameter	
	(+)	(-)
1	0 - 200 % of C_{ch}	5 % of C_{cl}
2	5 % of C_{ch}	0 - 200 % of C_{cl}
3	0 - 200 % of C_{ch}	20 % of C_{cl}
4	20 % of C_{ch}	0 - 200 % of C_{cl}

C_{ch} is critical damping of a linear SDOF system having the high stiffness of a two stiffness (i.e. bi-linear) system and C_{cl} is critical damping of a linear SDOF system having the low stiffness of a two-stiffness system.

For example, if the two stiffness system has stiffnesses K_h and K_l, then

$C_{ch} = 2\sqrt{K_h M}$ and $C_{cl} = 2\sqrt{K_l M}$ where (M) is the mass of the SDOF system.

Three different systems will be discussed in this section. They are a bilinear hysteretic system, a semi-active stiffness control system, and a linear elastic system.

System A: Bilinear System

Description of the system: The system discussed here is a bi-linear hysteretic system with stiffness of K_h =390 kips/in and K_l =39 kips/in. For each stiffness, the system carries a passive damping value related to the stiffness of the branch of the hysteresis loop.

That is, the passive damping ratio is assumed to be a constant multiple of $1/(2\sqrt{km})$ where k is 39 kips/in or 390 kips/in. The weight of the mass is 10 kips.

In this system, supplemental damping is controlled. That is, the stiffness of the system follows bi-linear hysteretic behavior according to their specified yield force, while the supplemental damping can be switched actively between two values according to the sign of the control parameter (*GV*BS, V*BS, or V*U*). The specified yield forces used in this study are 50 kips and 300 kips. For each yield force four cases are simulated using each control parameter (*GV*BS, V*BS, or V*U*). These cases are summarized in Table 1 and described below.

Case 1) Set the system damping to 5% of $2\sqrt{km}$ (k=39 kip/in) when the control parameter is *negative*; vary the system damping to 0%, 5%, 9%, 15%, 20%, ...200% of $2\sqrt{km}$ (k=390 kip/in) when the control parameter is positive. In this way we get curves for peak base shear, peak displacement, total energy input, and peak energy content for each control parameter under different yield force levels.

Case 2) Set the system damping to 5% of $2\sqrt{km}$ (k=390 kip/in) when the control parameter is *positive*; vary the system damping to 0%, 5%, 9%, 15%, 20%, ...200% of $2\sqrt{km}$ (k=39 kip/in) when the control parameter is negative.

Case 3) Set the system damping to 20% of $2\sqrt{km}$ (k=39 kip/in) when the control parameter is *negative*; vary the system damping to 0%, 5%, 9%, 15%, 20%, ...200% of $2\sqrt{km}$ (k=390 kip/in) when the control parameter is positive.

Case 4) Set the system damping to 20% of $2\sqrt{km}$ (k=390 kip/in) when the control parameter is *positive*; vary the system damping to 0%, 5%, 9%, 15%, 20%, ...200% of $2\sqrt{km}$ (k=39 kip/in) when the control parameter is negative.

For detailed results of the simulations please refer to pages (I)-(A)-*.

Observations: When the yield force level is lower, base shear, energy input and energy content response are smaller; however, the displacement is larger. From the results, it seems that using ***V*BS*** as the control parameter will provide somewhat better overall results over all ranges of damping. If we want a better overall result for combining *semi-active damping control* and *bilinear hysterestic stiffness*, it is recommended that we use a higher level of yield force with *V*BS* as the control parameter, and keep the controlled damping below 40% of the critical damping.

System B: Semi-Active Stiffness System

Description of the system: The system discussed here is a semi-active control system for both damping and stiffness. The weight of the system is 10 kips. The stiffness is *always* 390 kip/in when the control parameter is positive and 39 kip/in when the control parameter is negative.

Here we simulate the following 4 cases while the stiffness is always switched between 390 kip/in and 39 kip/in.

Case 1) Set the system damping to 5% of $2\sqrt{km}$ (k=39 kip/in) when the control parameter is *negative*; vary the system damping to 0%, 5%, 9%, 15%, 20%, ...200% of $2\sqrt{km}$ (k=390 kip/in) when the control parameter is positive. In this way we get curves for peak base shear, peak displacement, total energy input, and peak energy content for each control parameter, as damping is changed.

Case 2) Set the system damping to 5% of $2\sqrt{km}$ (k=390 kip/in) when the control parameter is *positive;* vary the system damping to 0%, 5%, 9%, 15%, 20%, ...200% of $2\sqrt{km}$ (k=39 kip/in) when the control parameter is negative.

Case 3) Set the system damping to 20% of $2\sqrt{km}$ (k=39 kip/in) when the control parameter is *negative*; vary the system damping to 0%, 5%, 9%, 15%, 20%, ...200% of $2\sqrt{km}$ (k=390 kip/in) when the control parameters is positive.

Case 4) Set the system damping to 20% of $2\sqrt{km}$ (k=390 kip/in) when the control parameter is *positive*; vary the system damping to 0%, 5%, 9%, 15%, 20%, ...200% of $2\sqrt{km}$ (k=39 kip/in) when the control parameter is negative.

For detailed results of the simulations please refer to page (I)-(B)-*.

Observations: For base shear and energy input, using *GV*BS* as the control parameter provides the best result in these cases. For the displacement, however, the result is about 3 times higher than using (*V*BS or V*U*) as the control parameter. If *V*BS* or *V*U* are used, base shear and displacement are almost insensitive to the amount of controlled damping used when the damping range is lower than 30%. As for energy content, it seems insensitive to the damping for all control parameters. The best control damping range is around 20% to 40% critical damping if the base shear is our main interest. (The peak displacement will keep decreasing as damping increases.)

System C: Linear System

Description of the system: The system discussed here is a fixed stiffness and semi-active damping control system. The mass is 10 kips. The stiffness of the system is always 390 kip/in. The damping of the system is switched between two values according to the sign of the control parameters.

Here we simulate the following 4 cases with the stiffness remaining constant at *390 kip/in* .

Case 1) Set the system damping to *5%* when the control parameter is *negative*; vary the system damping to 0%, 5%, 9%, 15%, 20%, ...200% when the control parameter is positive. In this way we get curves for peak base shear, peak displacement, total energy input, and peak energy content for each control parameter.

Case 2) Set the system damping to *5%* when the control parameter is *positive*; vary the system damping to 0%, 5%, 9%, 15%, 20%, ...200% when the control parameter is negative.

Case 3) Set the system damping to *20%* when the control parameter is *negative*; vary the system damping to 0%, 5%, 9%, 15%, 20%, ...200% when the control parameter is positive.

Case 4) Set the system damping to *20%* when the control parameter is *positive*; vary the system damping to 0%, 5%, 9%, 15%, 20%, ...200% when the control parameter is negative.

For detailed results of the simulations please refer to page (I)-(C)-*.

Observations: Semi-active damping control improves the response only for low levels of controlled damping in these cases. For base shear, if the fixed damping is 5%, then active control can reduce the base shear up to one half compared to the uncontrolled with 5% damping system. If the fix damping is 20%, then active control can hardly improve the performance compared to the uncontrolled 20% damping system. All the three control parameters provided similar results. The best control switch target damping range is around 20% to 40% critical damping if the base shear is our main interest. (The displacement will decrease as the damping increases.)

Overall Comments

1. The displacement and energy content decrease as the damping increases.

2. Overall, the best range in semi-active damping control is 20 % to 40% of critical damping in these studies.

3. From these simulations it appears that bi-linear hysteretic systems with lower yield forces result in improved peak base shear but increased peak relative displacement under the effect of the control strategy.

4. The reversal of the polarity of the damping control rule does not result in dramatic changes in the system behavior. This suggests that the three control parameters ($GV*BS$), ($V*BS$), and ($V*U$) are not the appropriate control parameters for damping control.

5. It seems that if we perform only semi-active damping control, the improvement in base shear response from a fixed damping system (i.e. a system without control) will reduce as the fixed damping increases. The improvement is not that significant if the stiffness is constant. Therefore, the next part of the report focuses on the stiffness control only.

Section II Semi-Active Stiffness Control

In this section, the system with 5% critical damping is discussed first in order to see which control algorithm will yield the best overall result. The reason for using 5% critical damping is that the damping of most existing structures is around 3% to 5%. After the control algorithm was selected, different damping cases were tried in order to observe the sensitivity to damping.

System A: Semi-Active Stiffness 5% Fix Damping Case

Description of the system: The system discussed here is a fixed damping and semi-active stiffness control system. The damping of the system is 5% of $2\sqrt{km}$ (k=390 kip/in). The mass of the system is 10 kips. When the control parameter is positive, the stiffness of the system is 390 kip/in; when it is negative, the stiffness of the system is pk*390 kip/in, where pk is the stiffness ratio ,and varies from 0.01, 0.1, 0.2, 0.3, ...to 1.0. When pk=1.0, the system has no control (linear SDOF with k=390kip/in, mg=10 kips, c=5% critical damping $= (0.05)2\sqrt{km}$).

For detailed results of the simulations please refer to page (II)-(A)-*.

Observations: If *(BS*GV)* is used as the control parameter, then the base shear will have a sharp drop, but displacement will increase when the stiffness ratio pk is small. This kind of behavior is not desirable. If we use *V*BS* or *V*U*, all the response parameters (base shear, displacement, and energy content) will improve (decrease) as the stiffness ratio becomes smaller. However, for stiffness ratios below 0.2, only marginal improvement in the value of peak base shear, peak displacement, and peak energy content are observed. Therefore, overall ***V*BS*** seems to provide the best control result. The difference between using *V*BS* and using *V*U* is very small.

System B: *V*BS* for Different Damping %

Because ***V*BS*** yields the best overall stiffness control result, it will be used here as the only control parameter. The goal is to find out how the system will respond under different damping conditions.

Description of the system: The system considered here is a fixed damping and semi-active stiffness control system. The mass of the system is 10 kips. Fix the damping of the system to 3% of $2\sqrt{km}$ (k=390 kip/in) . When $V*BS$ is positive, the stiffness of the system is 390 kip/in; when it is negative, the stiffness of the system is pk*390 kip/in, where pk is the stiffness ratio, and varies from 0.01, 0.1, 0.2, 0.3, ...to 1.0. Similarly, we change the damping to 5%, 10%, 15%, 20%, 30%, 40%, 50%, 75%, 100%, 150%, 200% of critical damping.

For detailed results of the simulations please refer to page (II)-(B)-*.

Observations: The performance improvement due to semi-active stiffness control decreases as the passive damping increases. (i.e. If we have a system with 3% critical damping and 5% critical damping, the semi-active stiffness control has a greater effect in the 3% case than in the 5% case.) Semi-active stiffness control can reduce peak response quantities (base shear, relative displacement, energy input, total energy) to levels comparable to a passive system damped to 30% - 50% of critical without the accompanying increase in base shear that high passive damping entails. The response will improve (displacement, energy input, and energy content decreases) as damping increases except for the base shear. When the damping is higher than 30%, the base shear increases as the damping increases.

Overall Comments

1. From these studies, it seems that semi-active stiffness control improves the performance only when the system damping is less than 30% critical. If the damping of the system is higher than 30%, then the semi-active stiffness control is almost ineffective.

2. In the cases considered in this report, it seems that stiffness ratio, *pk*, of around 0.1 to 0.3 will provide the best control result.

Conclusion

Based on the simulation results, the following conclusions can be drawn.

1. It seems that the use of relative velocity times base shear ($V*BS$) as the control parameter provides the best results for semi-active stiffness control. If we use ground velocity times base shear ($GV*BS$), even though we can minimize the energy input, the overall response (including displacement) is not always the best.

2. The effect of the semi-active stiffness control decreases with increased passive damping. For passive damping above 30%, the semi-active stiffness control has little effect.

3. For semi-active damping control using the mentioned algorithms, in order to obtain the best overall control result, it is recommended that 20% to 40% of critical damping be set as the maximum system damping. If a higher value of maximum damping were chosen, the response will only become more undesirable.

4. It seems that semi-active stiffness control is more effective than semi-active damping control. The semi-active stiffness control with 3% critical damping can reduce the base shear by about 65%; while the semi-active damping control with minimum damping of 5% can reduce the base shear by about 50%. The most effective stiffness ratio, pk, to be used in semi-active stiffness control seems to be around 0.1 to 0.3. For both types of control, the smaller the passive damping is (damping value between 0% to 30% critical damping), the more effective the active control is.

5. Semi-active stiffness control of a lightly damped structure reduce peak response quantities (displacement, energy content, total energy input) to levels comparable to a structure damped with 30% passive damping, without the accompanying increase in base shear associated with high damping.

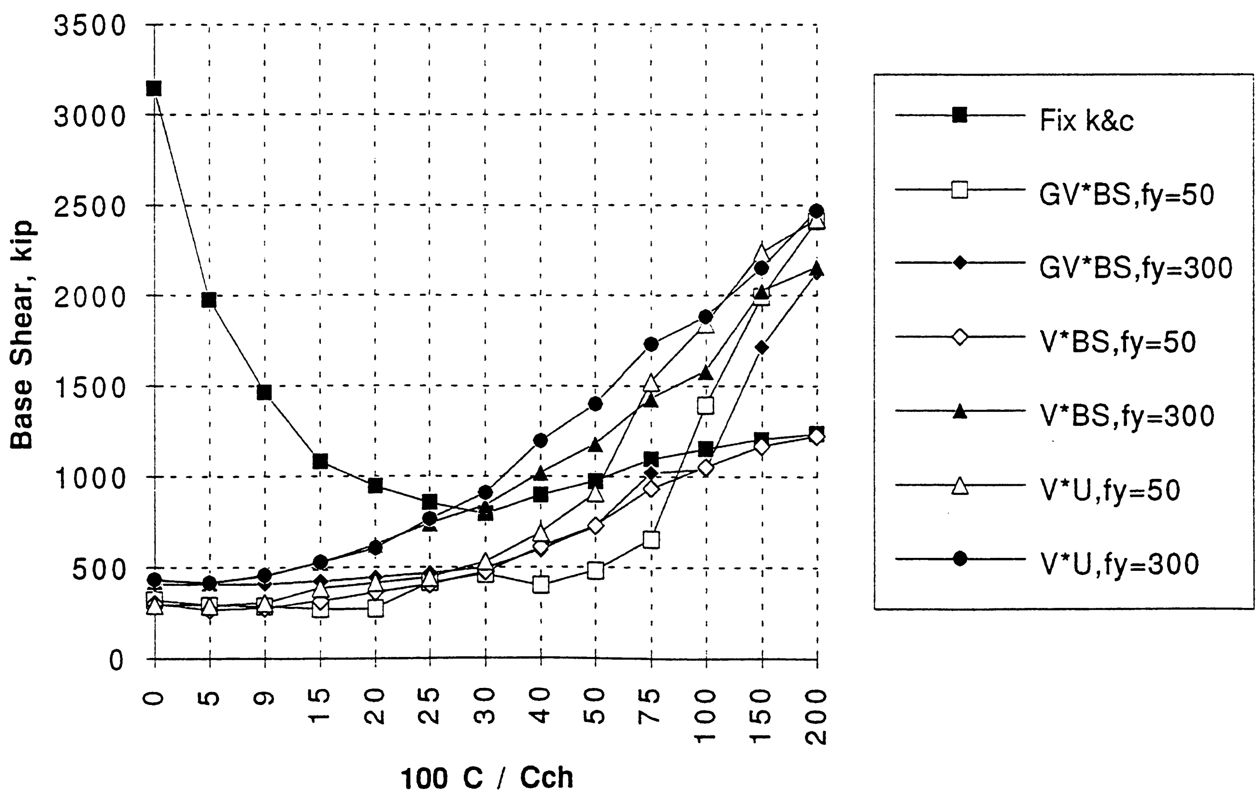
Hopefully, the results of this study will be useful in the decision making for applying semi-active control. Also, some reference values are provided for parameters to be used in semi-active control.

References

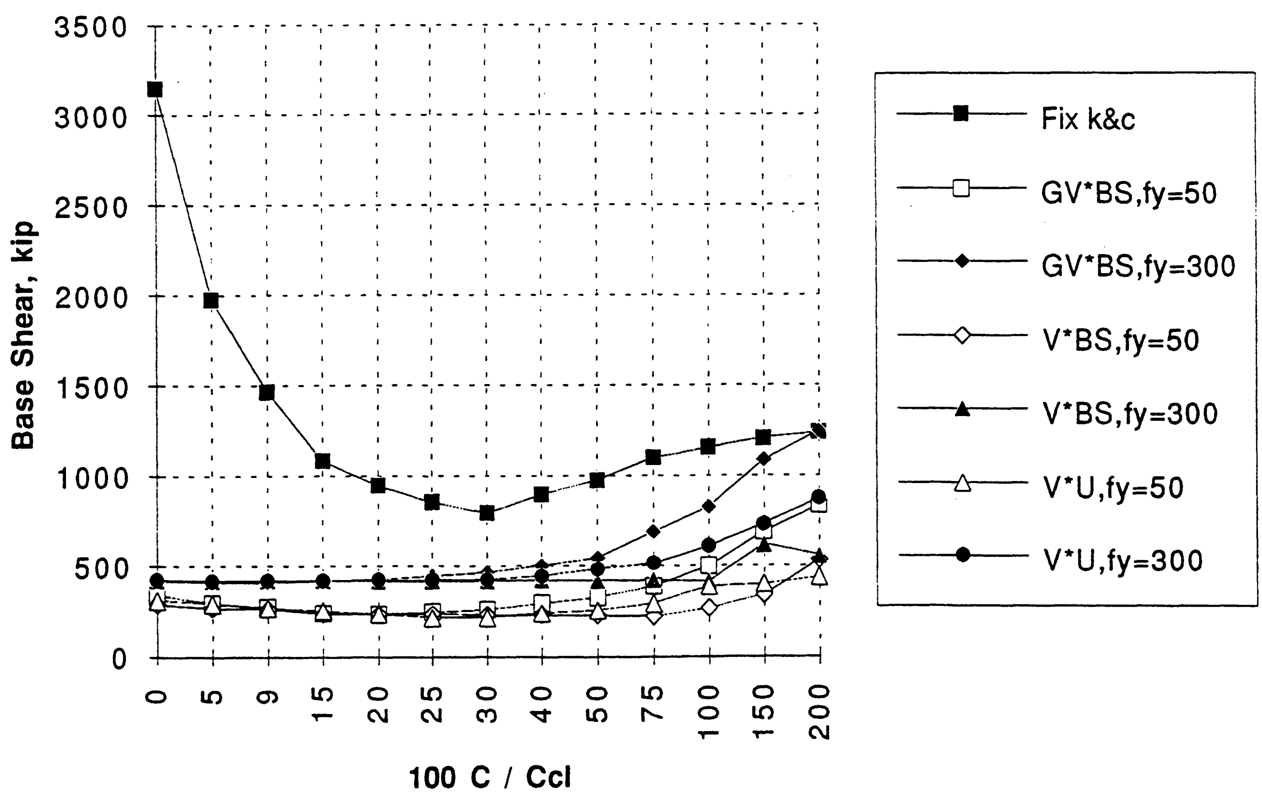
1. 1994 Edition NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings. FEMA 222/ January 1994.

2. Hanson, Robert D., and Firmansjah, Jodi, "Energy Concerns for Active Response Control," Proc. Japan National Symposium/workshop on Structural Response Control, July 1992.

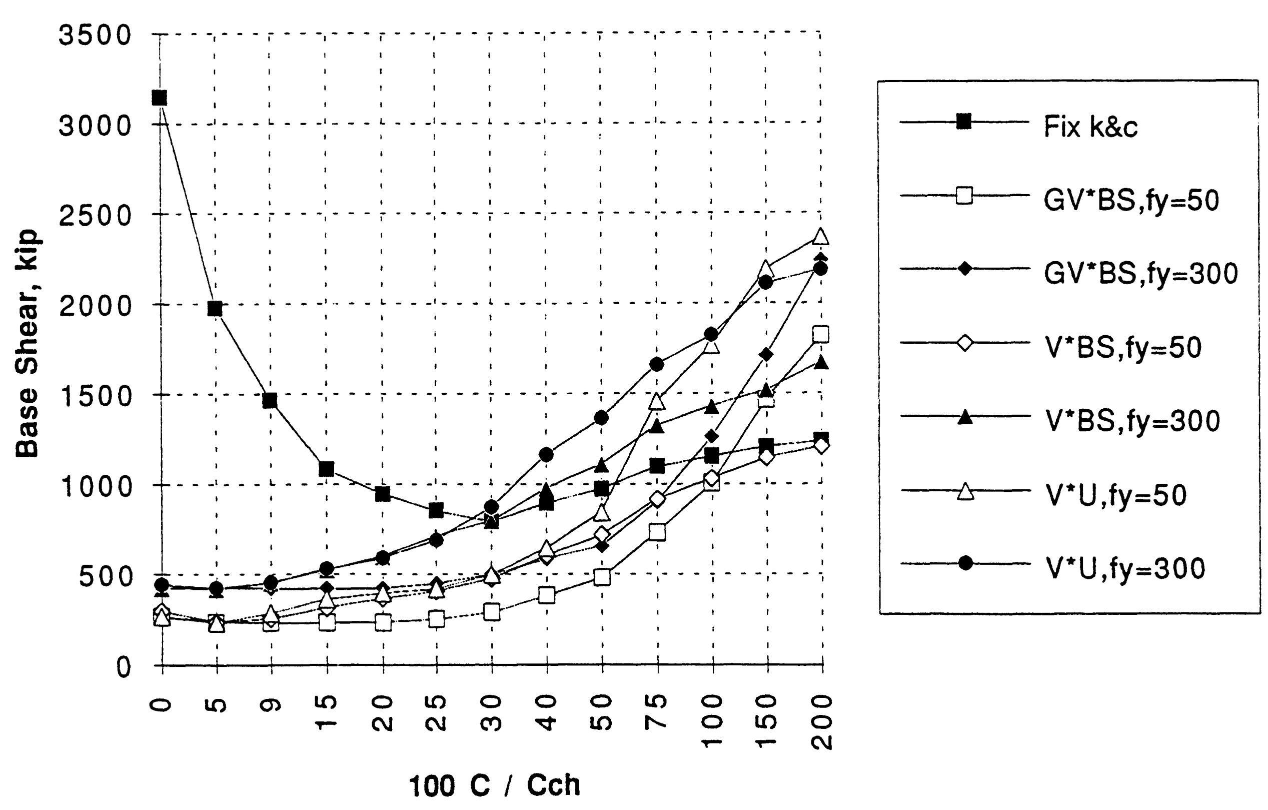
Description:	Here provide	**Fix k&c for comparison**	, represent the case without controling				
(Fixed damping ratio according to 390 kip/in, i.e. keep the same damping even in the range of 39 kip/in)							
(Different from the other columns, the 30% point means bilinear sys with 30% damping, no change in k&c.)							
The GV*BS,fy=50 column : when GV*BS is negative provide 5% damping according to39 kip/in (FIX),							
when GV*BS is positive provide c% damping according to 390 kip/in (VARY). The yield force of							
bilinear system is 50 kips.							
(30% point means when neg. GV*BS c=5% acc. to 39 kip/in; when pos. GV*BS c=30% acc. to 390 kip/in)							
Base shear (Bilinear 390, 39) Fix soft 5% (*.005)							
c(%)	Fix k&c	GV*BS,fy=50	GV*BS,fy=300	V*BS,fy=50	V*BS,fy=300	V*U,fy=50	V*U,fy=300
0	3144	320	410	301	429	295	434
5	1976	294	411	266	417	291	413
9	1465	284	411	277	454	304	455
15	1081	274	427	316	527	386	527
20	945	273	444	362	624	415	603
25	854	413	466	407	739	445	761
30	791	465	497	475	838	531	906
40	894	398	597	612	1018	691	1195
50	974	481	725	727	1179	907	1397
75	1095	658	1020	933	1434	1523	1726
100	1154	1394	1037	1054	1583	1843	1884
150	1205	1987	1711	1166	2023	2235	2150
200	1235	2411	2126	1226	2155	2421	2469



Description:	Here provide	**Fix k&c for comparison**	, represent the case without controling				
(Fixed damping ratio according to 390 kip/in, i.e. keep the same damping even in the range of 39 kip/in)							
(Different from the other columns, the 30% point means bilinear sys with 30% damping, no change in k&c.)							
The GV*BS,fy=50 column : when GV*BS is positive provide 5% damping according to390 kip/in(FIX),							
when GV*BS is negative provide c% damping according to 39 kip/in (VARY). The yield force of							
bilinear system is 50 kips.							
(30% point means when neg. GV*BS c=30% acc. to 39 kip/in; when pos. GV*BS c=5% acc. to 390 kip/in)							
Base shear (Bilinear 390, 39) Fix stiff 5% (005.*)							
c(%)	Fix k&c	GV*BS,fy=50	GV*BS,fy=300	V*BS,fy=50	V*BS,fy=300	V*U,fy=50	V*U,fy=300
0	3144	340	418	290	424	312	421
5	1976	294	411	266	417	291	413
9	1465	270	412	262	423	266	418
15	1081	242	417	236	421	257	419
20	945	237	424	237	418	233	423
25	854	244	443	235	418	218	421
30	791	258	463	228	419	218	425
40	894	291	502	228	422	239	446
50	974	324	542	226	419	254	481
75	1095	389	686	222	422	292	513
100	1154	499	828	265	416	388	609
150	1205	688	1083	339	617	401	733
200	1235	835	1242	530	559	438	872



Description:	Here provide	**Fix k&c for comparison**	, represent the case without controling				
(Fixed damping ratio according to 390 kip/in, i.e. keep the same damping even in the range of 39 kip/in)							
(Different from the other columns, the 30% point means bilinear sys with 30% damping, no change in k&c.)							
The GV*BS,fy=50 column : when GV*BS is negative provide 20% damping according to39 kip/in (FIX)							
when GV*BS is positive provide c% damping according to 390 kip/in (VARY). The yield force of							
bilinear system is 50 kips.							
(30% point means when neg. GV*BS c=20% acc. to 39 kip/in; when pos. GV*BS c=30% acc. to 390 kip/in)							
Base Shear (Bilinear 390, 39) Fix soft 20% (*.020)							
c(%)	Fix k&c	GV*BS,fy=50	GV*BS,fy=300	V*BS,fy=50	V*BS,fy=300	V*U,fy=50	V*U,fy=300
0	3144	267	424	298	424	268	441
5	1976	237	424	237	418	233	423
9	1465	233	423	256	453	287	454
15	1081	234	422	317	525	362	528
20	945	235	421	366	599	397	588
25	854	250	450	408	715	419	690
30	791	290	499	476	798	499	872
40	894	381	586	605	978	645	1163
50	974	479	656	716	1110	845	1362
75	1095	731	902	918	1323	1455	1659
100	1154	1003	1263	1031	1432	1770	1823
150	1205	1465	1710	1145	1514	2189	2106
200	1235	1818	2234	1204	1676	2362	2185



Description: Here provide **Fix k&c for comparison** , represent the case without controling

(Fixed damping ratio according to 390 kip/in, i.e. keep the same damping even in the range of 39 kip/in)

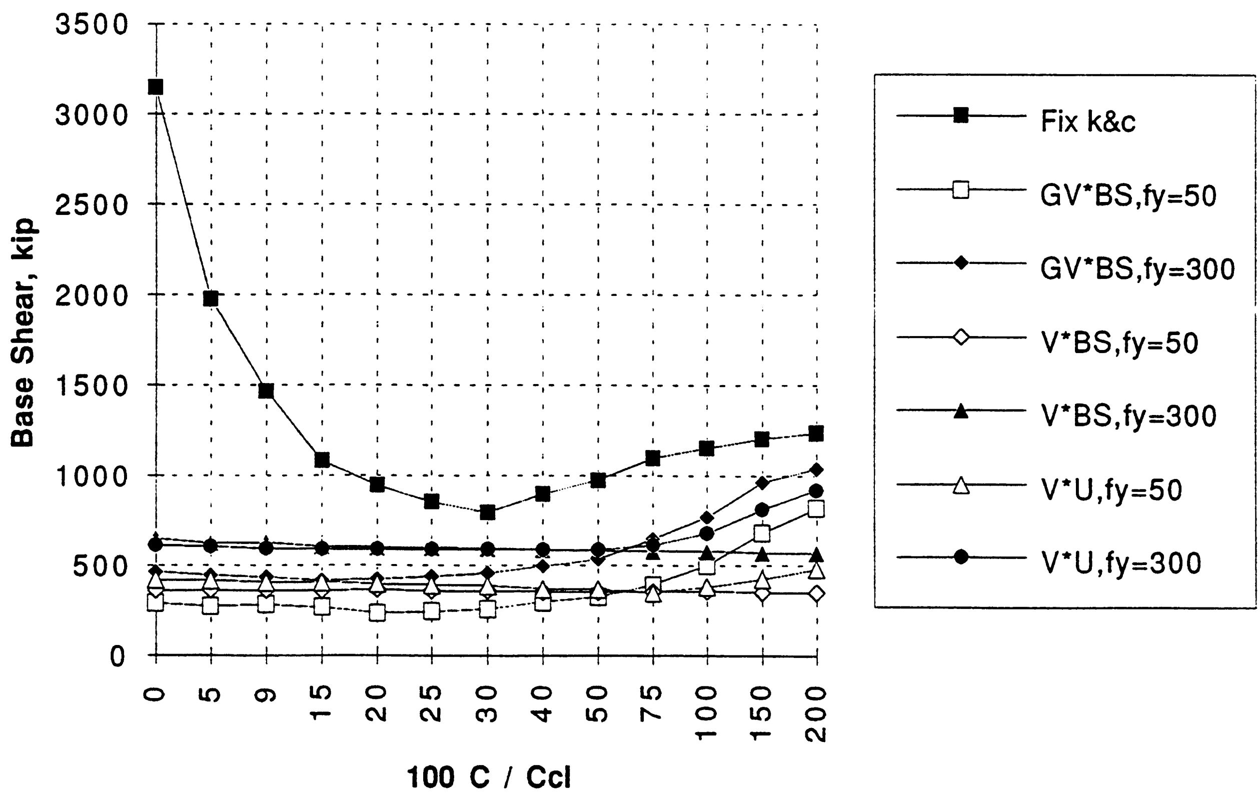
(Different from the other columns, the 30% point means bilinear sys with 30% damping, no change in k&c.)

The GV*BS,fy=50 column : when GV*BS is positive provide 20% damping according to390 kip/in(FIX)
when GV*BS is negative provide c% damping according to 39 kip/in (VARY). The yield force of
bilinear system is 50 kips.

(30% point means when neg. GV*BS c=30% acc. to 39 kip/in; when pos. GV*BS c=20% acc. to 390 kip/in)

Base shear (Bilinear 390, 39) Fix stiff 20% (020.*)

c(%)	Fix k&c	GV*BS,fy=50	GV*BS,fy=300	V*BS,fy=50	V*BS,fy=300	V*U,fy=50	V*U,fy=300
0	3144	288	462	360	649	417	611
5	1976	273	444	362	624	415	603
9	1465	280	432	362	626	405	591
15	1081	267	415	359	603	406	588
20	945	235	421	366	599	397	588
25	854	244	439	358	600	390	588
30	791	258	457	358	592	386	588
40	894	295	494	355	584	369	586
50	974	324	532	354	581	365	585
75	1095	393	646	355	580	348	610
100	1154	500	770	358	581	380	678
150	1205	680	965	350	571	421	813
200	1235	818	1039	351	569	480	921



Description:	Here provide	**Fix k&c for comparison**	, represent the case without controling				
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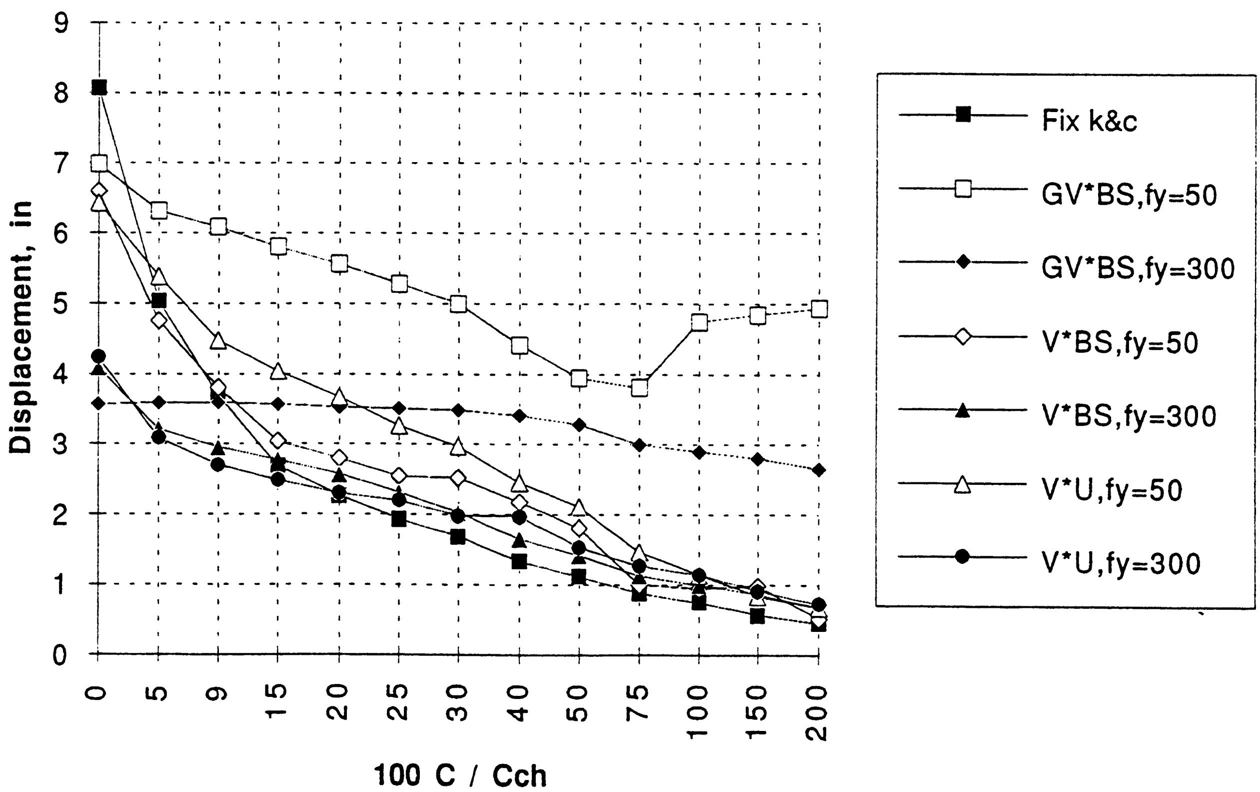
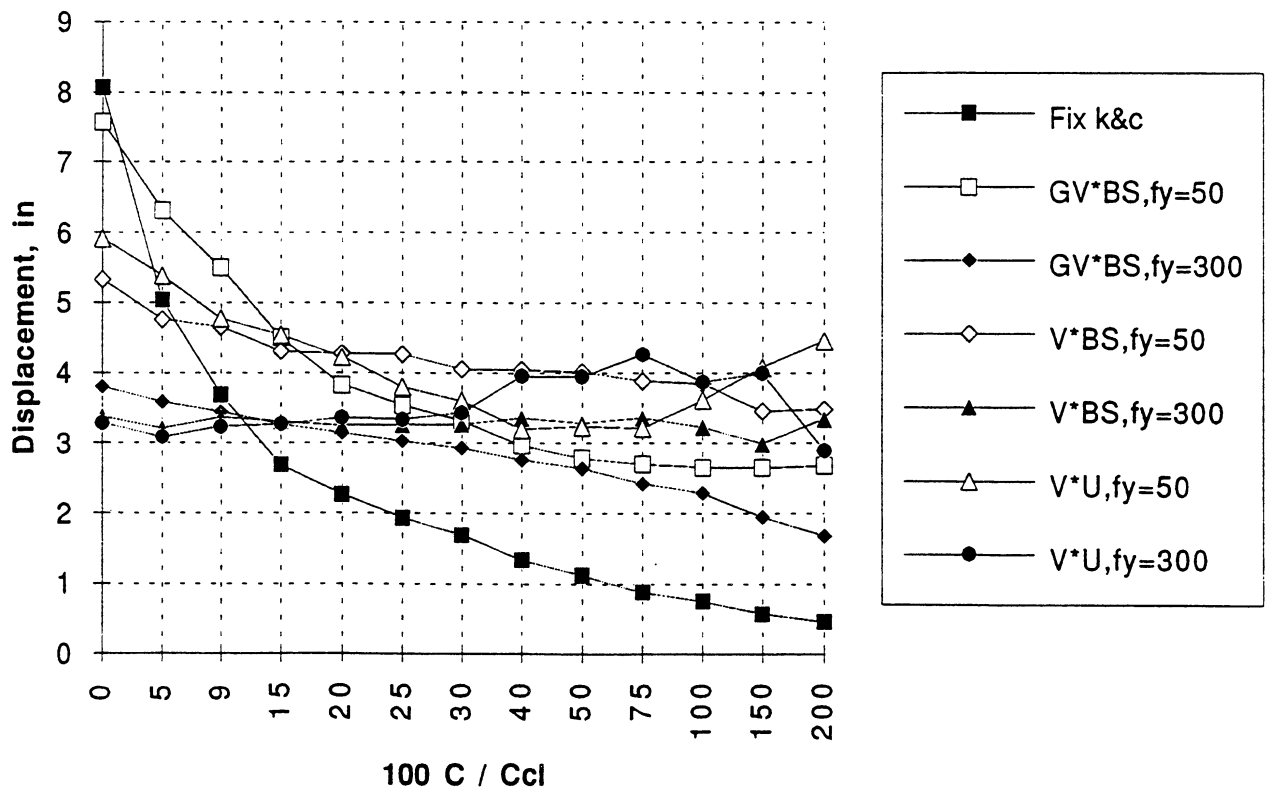
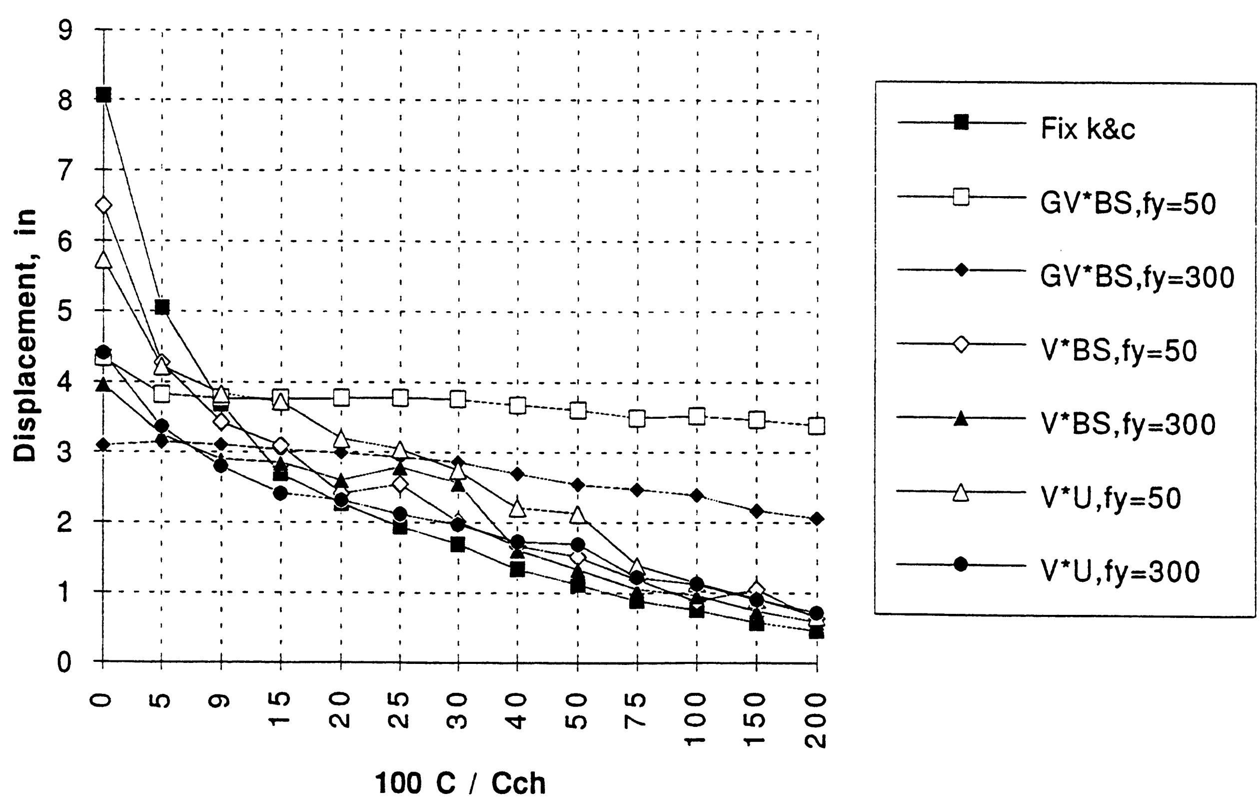
(Different from the other columns, the 30% point means bilinear sys with 30% damping, no change in k&c.)							
The GV*BS,fy=50 column : when GV*BS is negative provide 5% damping according to39 kip/in (FIX),							
when GV*BS is positive provide c% damping according to 390 kip/in (VARY). The yield force of							
bilinear system is 50 kips.							
(30% point means when neg. GV*BS c=5% acc. to 39 kip/in; when pos. GV*BS c=30% acc. to 390 kip/in)							
Displacement (Bilinear 390, 39) Fix soft 5% (*.005)							
c(%)	Fix k&c	GV*BS,fy=50	GV*BS,fy=300	V*BS,fy=50	V*BS,fy=300	V*U,fy=50	V*U,fy=300
0	8.06	6.971	3.558	6.583	4.08	6.417	4.23
5	5.041	6.308	3.587	4.754	3.204	5.389	3.083
9	3.682	6.078	3.584	3.803	2.953	4.474	2.7
15	2.683	5.8	3.553	3.032	2.772	4.031	2.474
20	2.259	5.555	3.515	2.785	2.563	3.668	2.291
25	1.935	5.281	3.496	2.532	2.315	3.251	2.197
30	1.684	4.996	3.474	2.518	2.028	2.959	1.978
40	1.33	4.414	3.397	2.176	1.653	2.445	1.972
50	1.119	3.937	3.272	1.806	1.414	2.11	1.532
75	0.876	3.798	2.991	1	1.129	1.47	1.256
100	0.747	4.743	2.894	0.939	0.985	1.146	1.145
150	0.572	4.846	2.802	0.981	0.859	0.83	0.913
200	0.456	4.927	2.647	0.519	0.675	0.674	0.727



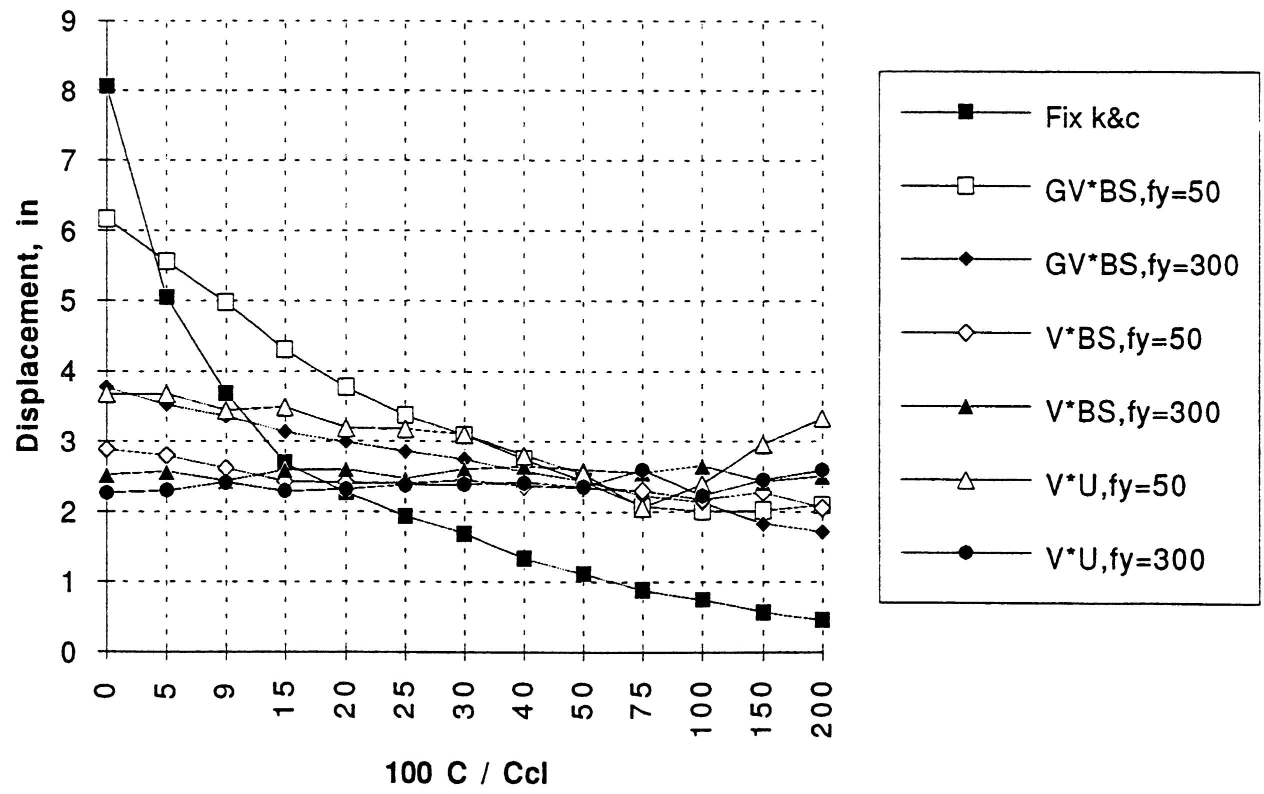
Description:	Here provide	**Fix k&c for comparison**	, represent the case without controling				
(Fixed damping ratio according to 390 kip/in, i.e. keep the same damping even in the range of 39 kip/in)							
(Different from the other columns, the 30% point means bilinear sys with 30% damping, no change in k&c.)							
The GV*BS,fy=50 column : when GV*BS is positive provide 5% damping according to390 kip/in(FIX),							
when GV*BS is negative provide c% damping according to 39 kip/in (VARY). The yield force of							
bilinear system is 50 kips.							
(30% point means when neg. GV*BS c=30% acc. to 39 kip/in; when pos. GV*BS c=5% acc. to 390 kip/in)							
Displacement (Bilinear 390, 39) Fix stiff 5% (005.*)							
c(%)	Fix k&c	GV*BS,fy=50	GV*BS,fy=300	V*BS,fy=50	V*BS,fy=300	V*U,fy=50	V*U,fy=300
0	8.06	7.565	3.795	5.332	3.375	5.911	3.288
5	5.041	6.308	3.587	4.754	3.204	5.389	3.083
9	3.682	5.493	3.445	4.65	3.363	4.763	3.236
15	2.683	4.488	3.261	4.298	3.303	4.534	3.261
20	2.259	3.822	3.134	4.265	3.248	4.219	3.351
25	1.935	3.539	3.023	4.262	3.252	3.79	3.33
30	1.684	3.311	2.926	4.041	3.261	3.6	3.431
40	1.33	2.959	2.764	4.038	3.353	3.2	3.95
50	1.119	2.776	2.636	4.004	3.289	3.235	3.936
75	0.876	2.691	2.418	3.882	3.356	3.212	4.245
100	0.747	2.647	2.28	3.838	3.226	3.603	3.868
150	0.572	2.639	1.94	3.449	2.992	4.071	3.987
200	0.456	2.673	1.676	3.475	3.347	4.448	2.892



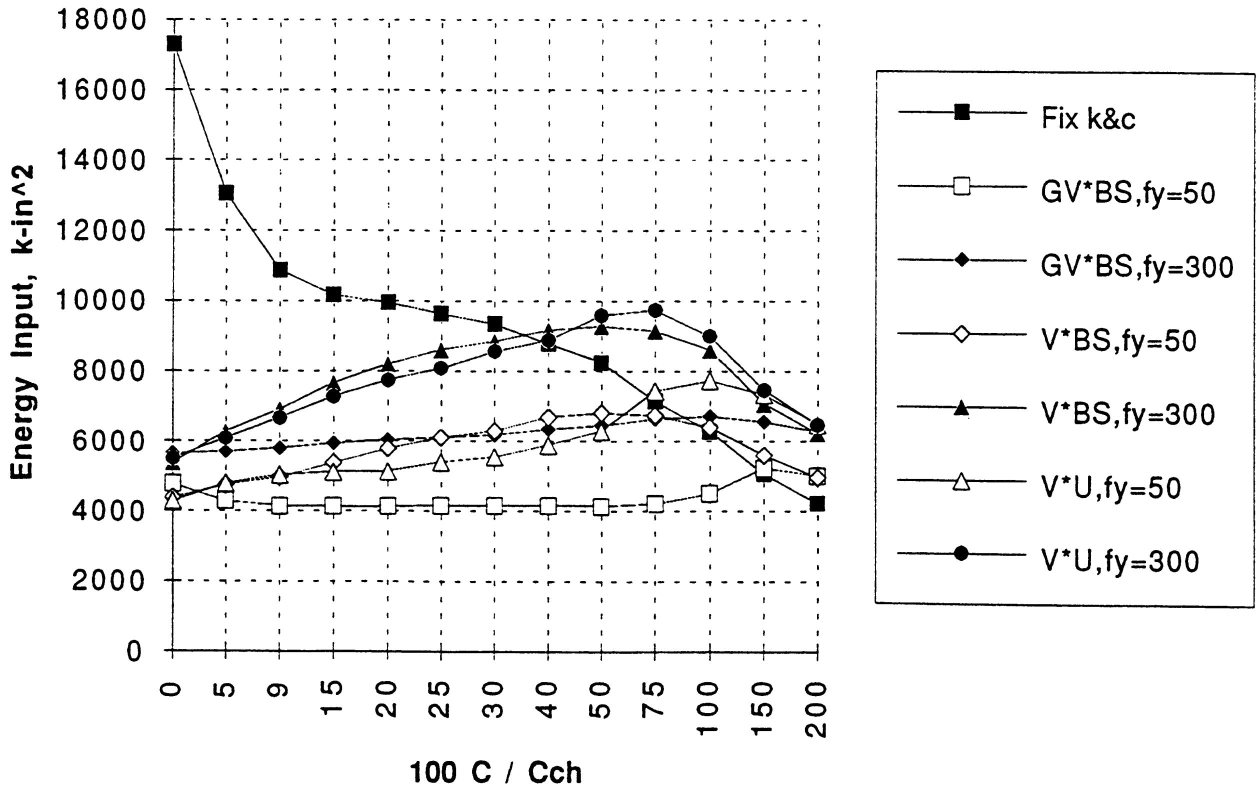
Description:	Here provide	**Fix k&c for comparison**	, represent the case without controling				
(Fixed damping ratio according to 390 kip/in, i.e. keep the same damping even in the range of 39 kip/in)							
(Different from the other columns, the 30% point means bilinear sys with 30% damping, no change in k&c.)							
The GV*BS,fy=50 column : when GV*BS is negative provide 20% damping according to39 kip/in (FIX)							
when GV*BS is positive provide c% damping according to 390 kip/in (VARY). The yield force of							
bilinear system is 50 kips.							
(30% point means when neg. GV*BS c=20% acc. to 39 kip/in; when pos. GV*BS c=30% acc. to 390 kip/in)							
Displacement (Bilinear 390, 39) Fix soft 20% (*.020)							
c(%)	Fix k&c	GV*BS,fy=50	GV*BS,fy=300	V*BS,fy=50	V*BS,fy=300	V*U,fy=50	V*U,fy=300
0	8.06	4.33	3.092	6.494	3.956	5.725	4.396
5	5.041	3.822	3.134	4.265	3.248	4.219	3.351
9	3.682	3.764	3.102	3.422	2.899	3.829	2.789
15	2.683	3.763	3.032	3.089	2.844	3.709	2.403
20	2.259	3.763	2.981	2.399	2.591	3.184	2.306
25	1.935	3.774	2.923	2.539	2.774	3.044	2.107
30	1.684	3.756	2.858	2.011	2.564	2.738	1.966
40	1.33	3.673	2.691	1.655	1.596	2.205	1.716
50	1.119	3.597	2.54	1.504	1.332	2.122	1.692
75	0.876	3.49	2.467	1.181	1.043	1.389	1.21
100	0.747	3.507	2.381	0.87	0.953	1.132	1.114
150	0.572	3.459	2.165	1.045	0.733	0.907	0.896
200	0.456	3.382	2.059	0.623	0.58	0.669	0.717



Description:	Here provide	**Fix k&c for comparison**	, represent the case without controling				
(Fixed damping ratio according to 390 kip/in, i.e. keep the same damping even in the range of 39 kip/in)							
(Different from the other columns, the 30% point means bilinear sys with 30% damping, no change in k&c.)							
The GV*BS,fy=50 column : when GV*BS is positive provide 20% damping according to390 kip/in(FIX)							
when GV*BS is negative provide c% damping according to 39 kip/in (VARY). The yield force of							
bilinear system is 50 kips.							
(30% point means when neg. GV*BS c=30% acc. to 39 kip/in; when pos. GV*BS c=20% acc. to 390 kip/in)							
Displacement (Bilinear 390, 39) Fix stiff 20% (020.*)							
c(%)	Fix k&c	GV*BS,fy=50	GV*BS,fy=300	V*BS,fy=50	V*BS,fy=300	V*U,fy=50	V*U,fy=300
0	8.06	6.167	3.762	2.872	2.519	3.676	2.258
5	5.041	5.555	3.515	2.785	2.563	3.668	2.291
9	3.682	4.964	3.348	2.617	2.428	3.441	2.407
15	2.683	4.299	3.129	2.421	2.585	3.491	2.282
20	2.259	3.763	2.981	2.399	2.591	3.184	2.306
25	1.935	3.367	2.849	2.394	2.456	3.169	2.367
30	1.684	3.088	2.739	2.443	2.601	3.095	2.384
40	1.33	2.743	2.561	2.363	2.643	2.8	2.41
50	1.119	2.425	2.43	2.329	2.594	2.536	2.336
75	0.876	2.063	2.225	2.297	2.548	2.05	2.588
100	0.747	2.003	2.122	2.164	2.651	2.38	2.221
150	0.572	2.009	1.821	2.269	2.413	2.95	2.435
200	0.456	2.088	1.709	2.048	2.498	3.325	2.588



Description:	Here provide	**Fix k&c for comparison**	, represent the case without controling				
(Fixed damping ratio according to 390 kip/in, i.e. keep the same damping even in the range of 39 kip/in)							
(Different from the other columns, the 30% point means bilinear sys with 30% damping, no change in k&c.)							
The GV*BS,fy=50 column : when GV*BS is negative provide 5% damping according to39 kip/in (FIX),							
when GV*BS is positive provide c% damping according to 390 kip/in (VARY). The yield force of							
bilinear system is 50 kips.							
(30% point means when neg. GV*BS c=5% acc. to 39 kip/in; when pos. GV*BS c=30% acc. to 390 kip/in)							
Energy Input (Bilinear 390, 39) Fix soft 5% (*.005)							
c(%)	Fix k&c	GV*BS,fy=50	GV*BS,fy=300	V*BS,fy=50	V*BS,fy=300	V*U,fy=50	V*U,fy=300
0	17288	4760	5628	4374	5361	4267	5489
5	13023	4273	5685	4737	6275	4771	6083
9	10868	4143	5794	4963	6906	5021	6656
15	10150	4109	5934	5365	7663	5103	7277
20	9937	4123	6028	5777	8194	5136	7739
25	9634	4145	6107	6098	8601	5396	8072
30	9326	4158	6186	6291	8856	5544	8562
40	8759	4153	6334	6678	9154	5888	8869
50	8237	4135	6444	6804	9272	6289	9585
75	7138	4197	6636	6723	9134	7423	9715
100	6277	4478	6709	6395	8585	7720	8987
150	5042	5222	6545	5598	7073	7325	7468
200	4210	5001	6279	4962	6215	6486	6463



Description: Here provide **Fix k&c for comparison** , represent the case without controling

(Fixed damping ratio according to 390 kip/in, i.e. keep the same damping even in the range of 39 kip/in)

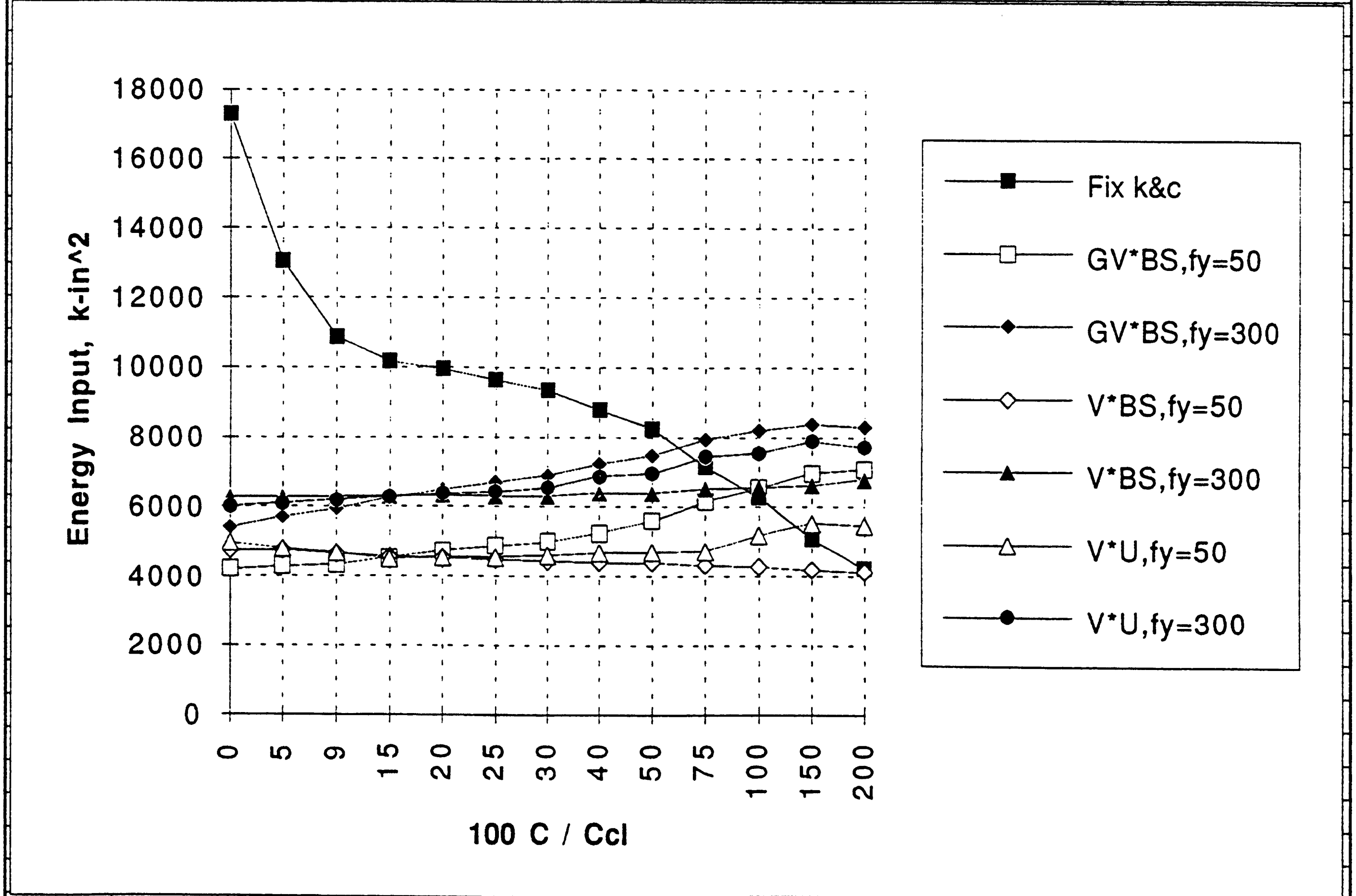
(Different from the other columns, the 30% point means bilinear sys with 30% damping, no change in k&c.)

The GV*BS,fy=50 column : when GV*BS is positive provide 5% damping according to390 kip/in(FIX), when GV*BS is negative provide c% damping according to 39 kip/in (VARY). The yield force of bilinear system is 50 kips.

(30% point means when neg. GV*BS c=30% acc. to 39 kip/in; when pos. GV*BS c=5% acc. to 390 kip/in)

Energy Input (Bilinear 390, 39) Fix stiff 5% (005.*)

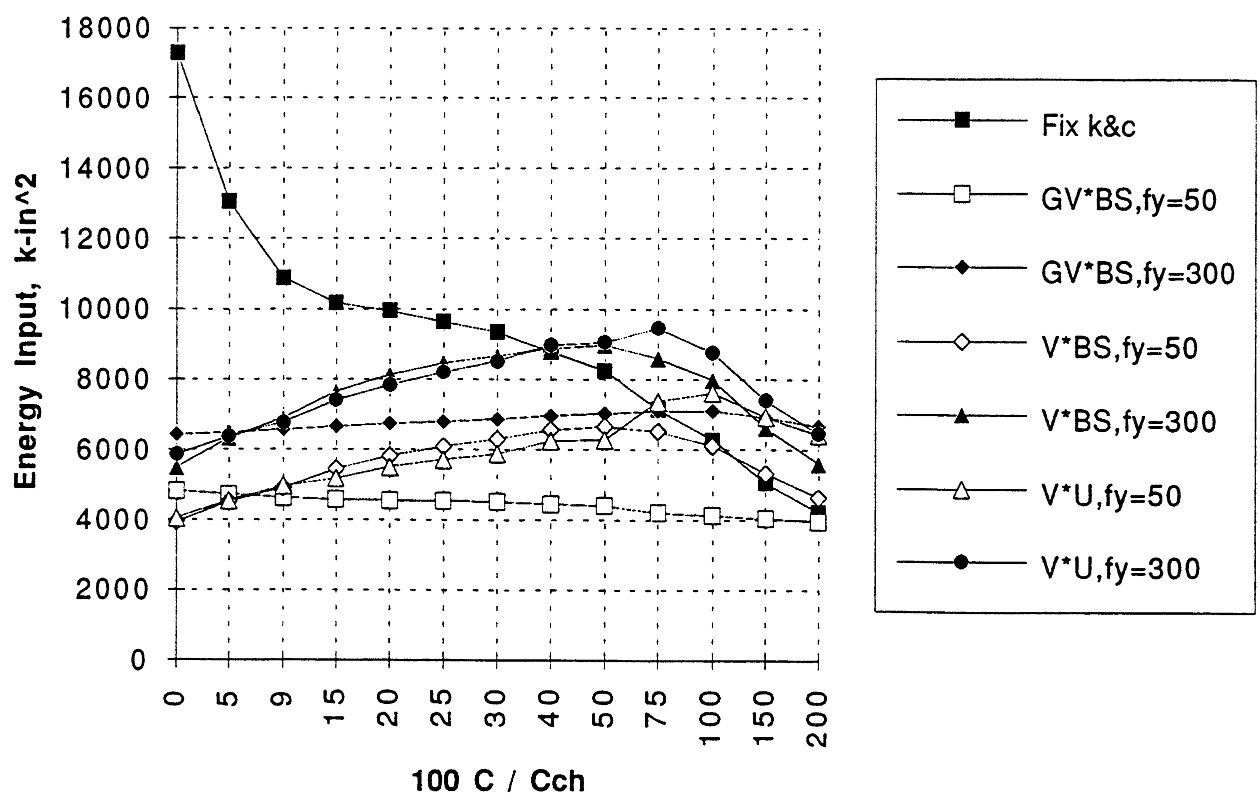
c(%)	Fix k&c	GV*BS,fy=50	GV*BS,fy=300	V*BS,fy=50	V*BS,fy=300	V*U,fy=50	V*U,fy=300
0	17288	4191	5386	4738	6260	4954	6001
5	13023	4273	5685	4737	6275	4771	6083
9	10868	4334	5923	4635	6283	4662	6168
15	10150	4532	6242	4542	6304	4491	6284
20	9937	4713	6474	4497	6312	4536	6362
25	9634	4856	6689	4458	6302	4552	6408
30	9326	4969	6880	4427	6298	4594	6528
40	8759	5228	7202	4394	6383	4666	6854
50	8237	5576	7456	4391	6387	4687	6930
75	7138	6146	7924	4308	6508	4711	7421
100	6277	6533	8177	4280	6543	5175	7544
150	5042	6962	8360	4168	6611	5520	7875
200	4210	7082	8286	4113	6792	5436	7699



Description:	Here provide **Fix k&c for comparison** , represent the case without controling
(Fixed damping ratio according to 390 kip/in, i.e. keep the same damping even in the range of 39 kip/in)	
(Different from the other columns, the 30% point means bilinear sys with 30% damping, no change in k&c.)	
The GV*BS,fy=50 column : when GV*BS is negative provide 20% damping according to39 kip/in (FIX)	
when GV*BS is positive provide c% damping according to 390 kip/in (VARY). The yield force of	
bilinear system is 50 kips.	
(30% point means when neg. GV*BS c=20% acc. to 39 kip/in; when pos. GV*BS c=30% acc. to 390 kip/in)	

Energy Input (Bilinear 390, 39) Fix soft 20% (*.020)

c(%)	Fix k&c	GV*BS,fy=50	GV*BS,fy=300	V*BS,fy=50	V*BS,fy=300	V*U,fy=50	V*U,fy=300
0	17288	4817	6416	3922	5477	4037	5846
5	13023	4713	6474	4497	6312	4536	6362
9	10868	4621	6546	4893	6873	4946	6769
15	10150	4571	6650	5449	7633	5163	7381
20	9937	4549	6726	5815	8108	5489	7811
25	9634	4538	6792	6080	8453	5719	8186
30	9326	4513	6852	6288	8653	5872	8513
40	8759	4449	6947	6541	8870	6234	8972
50	8237	4386	7022	6642	8961	6267	9033
75	7138	4193	7100	6508	8594	7360	9447
100	6277	4115	7094	6104	7980	7598	8758
150	5042	4016	6899	5316	6613	6911	7380
200	4210	3962	6669	4632	5621	6412	6444



Description: Here provide **Fix k&c for comparison** , represent the case without controling

(Fixed damping ratio according to 390 kip/in, i.e. keep the same damping even in the range of 39 kip/in)

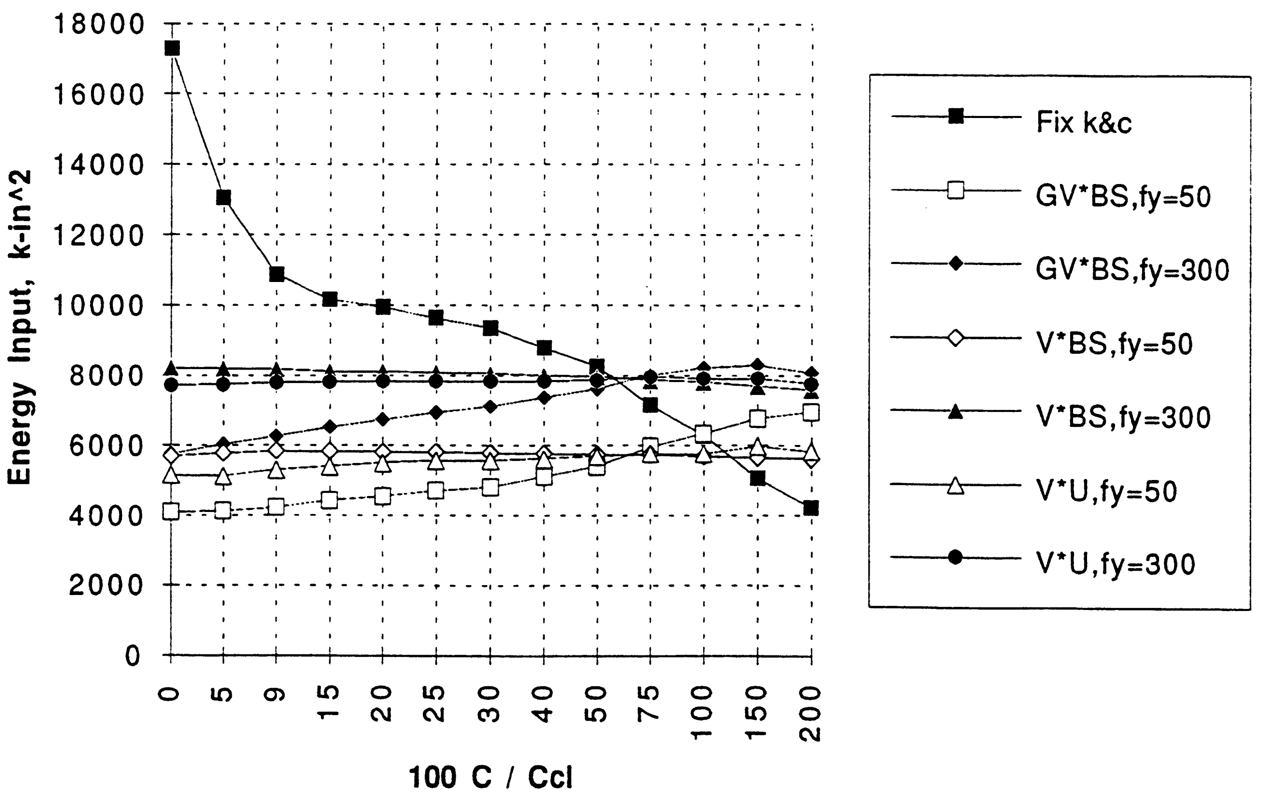
(Different from the other columns, the 30% point means bilinear sys with 30% damping, no change in k&c.)

The GV*BS,fy=50 column : when GV*BS is positive provide 20% damping according to390 kip/in(FIX) when GV*BS is negative provide c% damping according to 39 kip/in (VARY). The yield force of bilinear system is 50 kips.

(30% point means when neg. GV*BS c=30% acc. to 39 kip/in; when pos. GV*BS c=20% acc. to 390 kip/in)

Energy Input (Bilinear 390, 39) Fix stiff 20% (020.*)

c(%)	Fix k&c	GV*BS,fy=50	GV*BS,fy=300	V*BS,fy=50	V*BS,fy=300	V*U,fy=50	V*U,fy=300
0	17288	4073	5750	5691	8208	5140	7694
5	13023	4123	6028	5777	8194	5136	7739
9	10868	4218	6229	5827	8173	5303	7766
15	10150	4422	6512	5834	8107	5404	7795
20	9937	4549	6726	5815	8108	5489	7811
25	9634	4705	6916	5805	8066	5560	7820
30	9326	4801	7085	5772	8046	5567	7819
40	8759	5115	7372	5754	7983	5615	7822
50	8237	5392	7603	5738	7953	5696	7849
75	7138	5939	7997	5726	7860	5759	7958
100	6277	6322	8200	5678	7788	5761	7884
150	5042	6761	8277	5643	7668	5962	7891
200	4210	6932	8067	5606	7578	5823	7752



Description:	Here provide	**Fix k&c for comparison**	, represent the case without controling

(Fixed damping ratio according to 390 kip/in, i.e. keep the same damping even in the range of 39 kip/in)

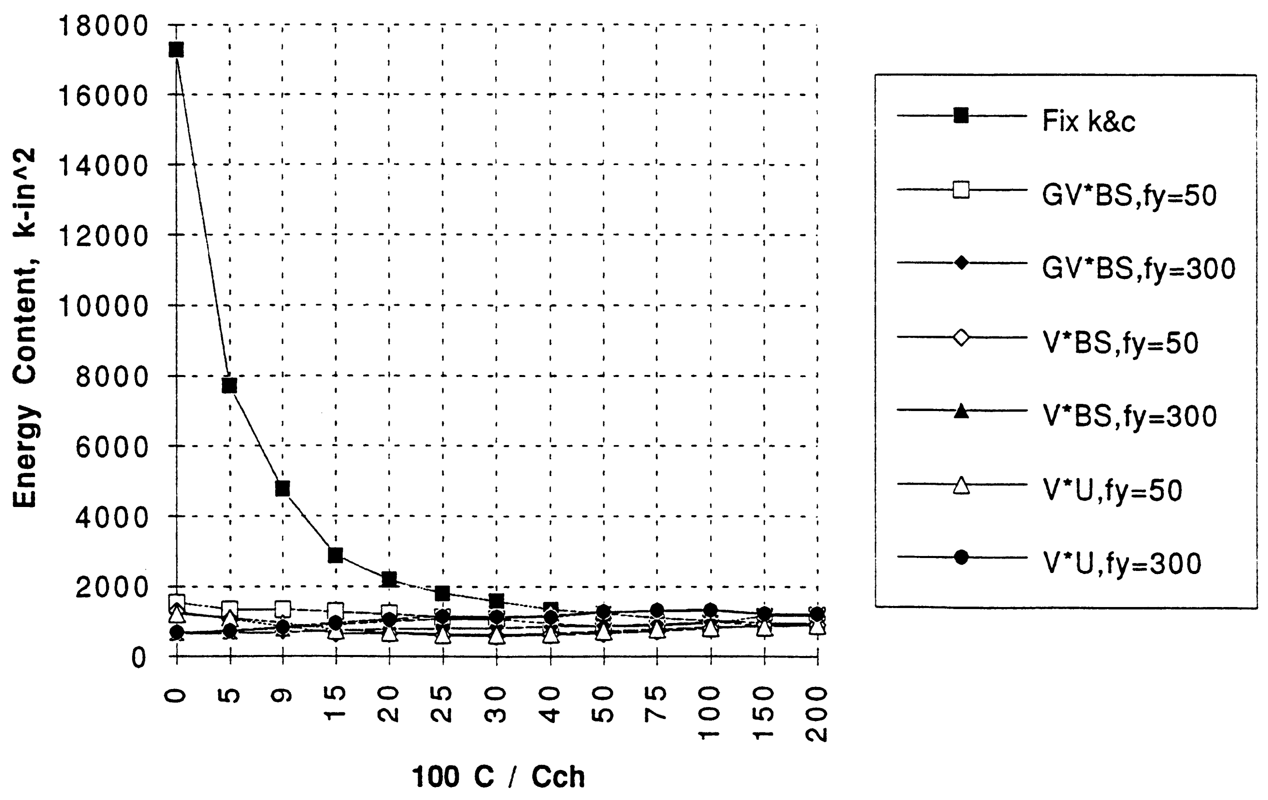
(Different from the other columns, the 30% point means bilinear sys with 30% damping, no change in k&c.)

The GV*BS,fy=50 column : when GV*BS is negative provide 5% damping according to39 kip/in (FIX), when GV*BS is positive provide c% damping according to 390 kip/in (VARY). The yield force of bilinear system is 50 kips.

(30% point means when neg. GV*BS c=5% acc. to 39 kip/in; when pos. GV*BS c=30% acc. to 390 kip/in)

KE + SE (Bilinear 390, 39) Fix soft 5% (*.005)

c(%)	Fix k&c	GV*BS,fy=50	GV*BS,fy=300	V*BS,fy=50	V*BS,fy=300	V*U,fy=50	V*U,fy=300
0	17288	1520	653	1278	665	1206	670
5	7689	1332	647	1031	711	1090	730
9	4759	1335	675	849	793	947	829
15	2866	1265	726	650	894	755	948
20	2171	1195	760	654	975	672	1030
25	1794	1125	791	601	1061	631	1134
30	1572	1056	814	569	1033	607	1138
40	1335	929	842	613	1172	646	1096
50	1215	839	860	648	1234	713	1264
75	1074	874	903	705	1294	773	1299
100	1007	932	953	792	1324	828	1292
150	935	1146	871	881	1194	842	1195
200	944	1162	882	889	1203	888	1224



Description: Here provide **Fix k&c for comparison** , represent the case without controling

(Fixed damping ratio according to 390 kip/in, i.e. keep the same damping even in the range of 39 kip/in)

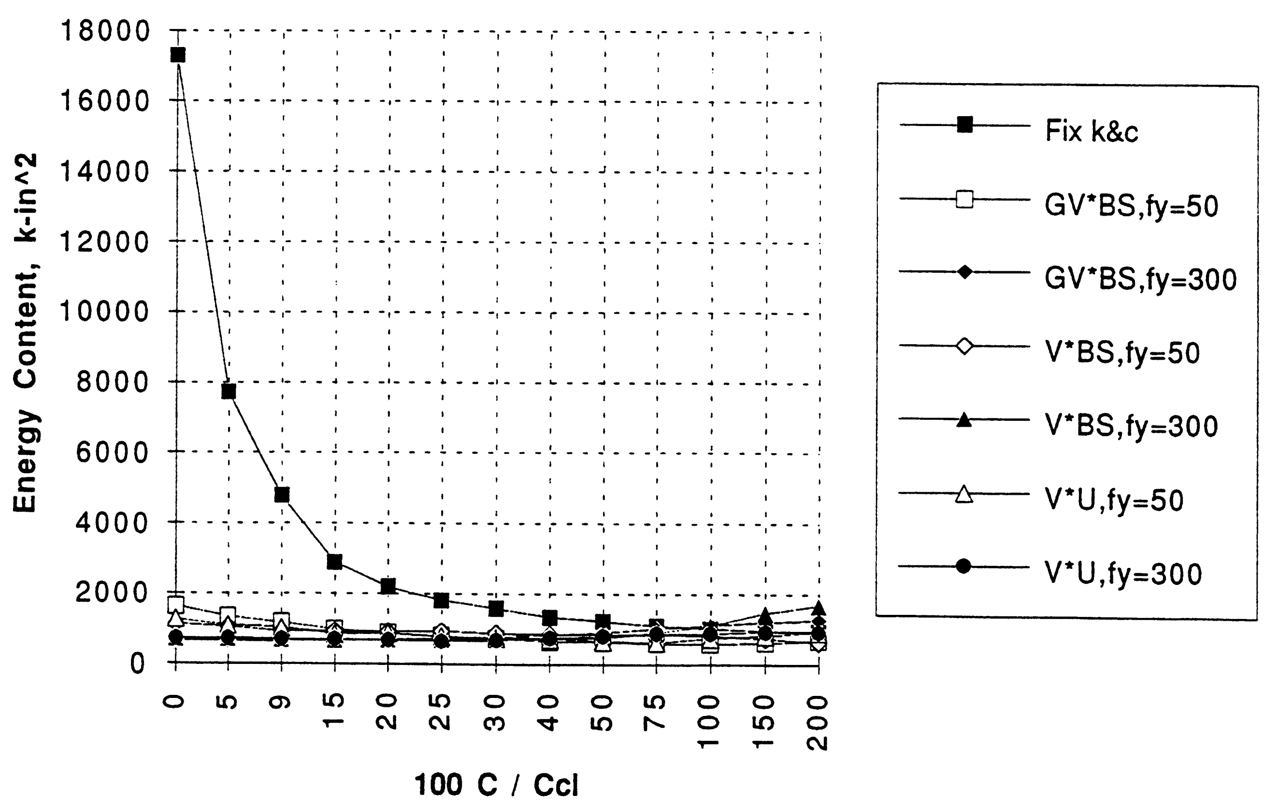
(Different from the other columns, the 30% point means bilinear sys with 30% damping, no change in k&c.)

The GV*BS,fy=50 column : when GV*BS is positive provide 5% damping according to390 kip/in(FIX), when GV*BS is negative provide c% damping according to 39 kip/in (VARY). The yield force of bilinear system is 50 kips.

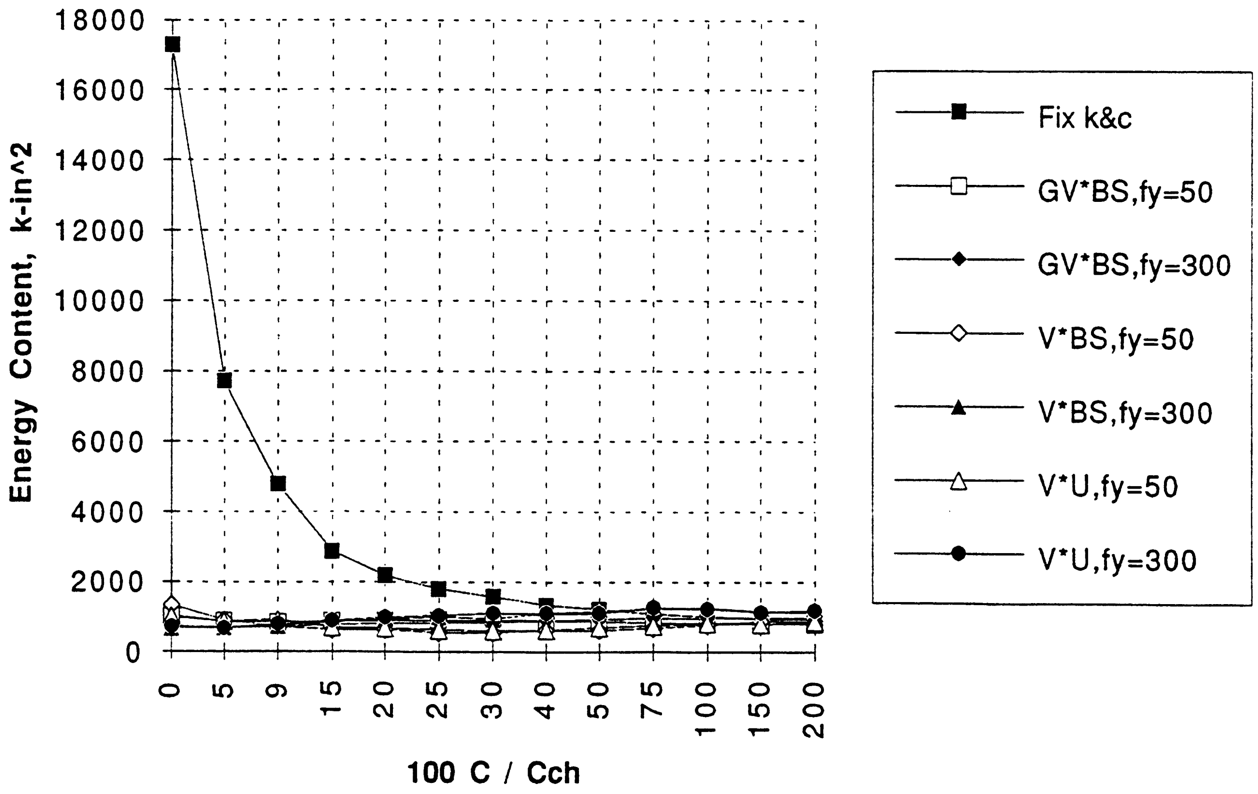
(30% point means when neg. GV*BS c=30% acc. to 39 kip/in; when pos. GV*BS c=5% acc. to 390 kip/in)

KE + SE (Bilinear 390, 39) Fix stiff 5% (005.*)

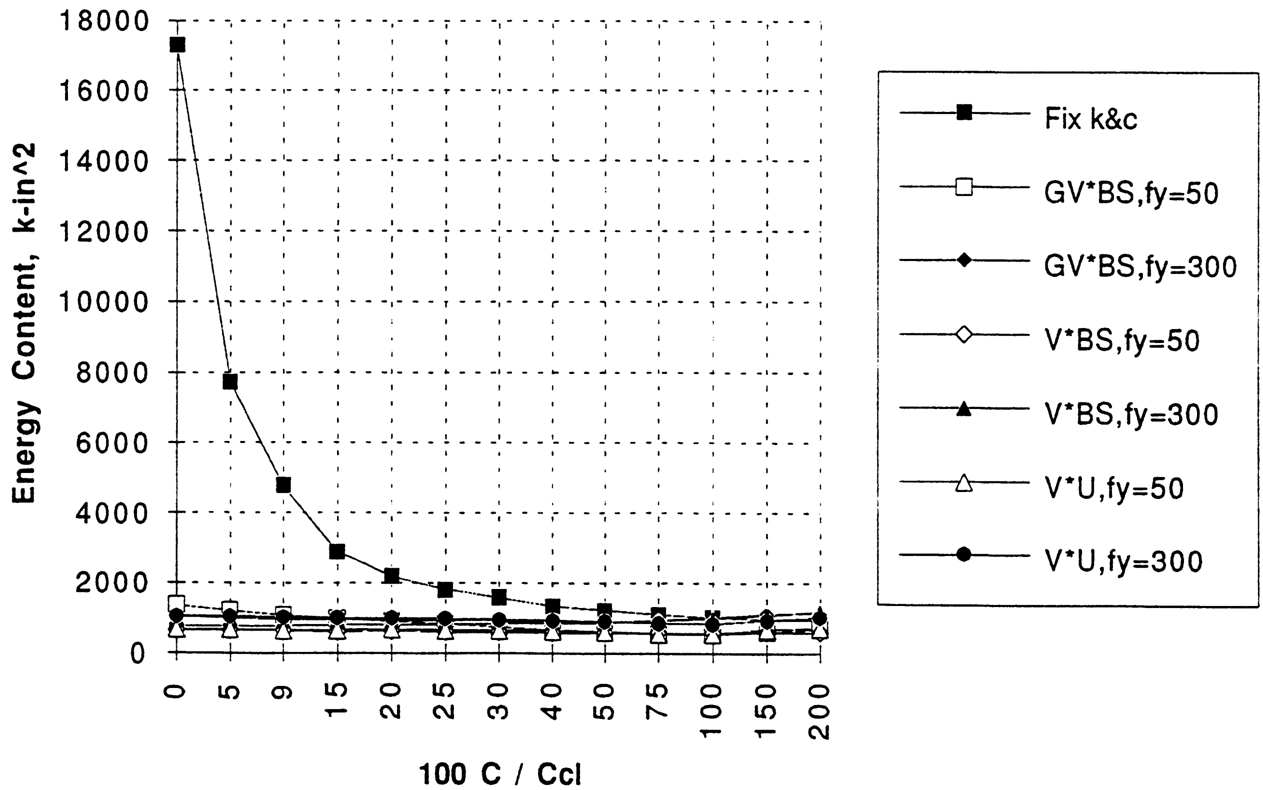
c(%)	Fix k&c	GV*BS,fy=50	GV*BS,fy=300	V*BS,fy=50	V*BS,fy=300	V*U,fy=50	V*U,fy=300
0	17288	1628	661	1113	719	1249	731
5	7689	1332	647	1031	711	1090	730
9	4759	1158	658	912	697	1027	694
15	2866	956	673	929	678	852	691
20	2171	858	700	897	683	866	666
25	1794	788	733	914	693	760	653
30	1572	724	763	861	719	755	674
40	1335	647	828	852	723	719	754
50	1215	628	879	854	758	652	782
75	1074	599	996	845	886	611	862
100	1007	577	1093	813	1094	751	874
150	935	605	1194	719	1454	806	914
200	944	679	1253	634	1666	916	908



Description:		Here provide	**Fix k&c for comparison**	, represent the case without controling			
(Fixed damping ratio according to 390 kip/in, i.e. keep the same damping even in the range of 39 kip/in)							
(Different from the other columns, the 30% point means bilinear sys with 30% damping, no change in k&c.)							
The GV*BS,fy=50 column : when GV*BS is negative provide 20% damping according to39 kip/in (FIX)							
when GV*BS is positive provide c% damping according to 390 kip/in (VARY). The yield force of							
bilinear system is 50 kips.							
(30% point means when neg. GV*BS c=20% acc. to 39 kip/in; when pos. GV*BS c=30% acc. to 390 kip/in)							
KE + SE (Bilinear 390, 39) Fix soft 20% (*.020)							
c(%)	Fix k&c	GV*BS,fy=50	GV*BS,fy=300	V*BS,fy=50	V*BS,fy=300	V*U,fy=50	V*U,fy=300
0	17288	1013	708	1328	673	1007	728
5	7689	858	700	897	683	866	666
9	4759	842	714	716	744	918	782
15	2866	875	764	636	851	694	885
20	2171	893	799	625	929	665	978
25	1794	900	831	559	996	624	1046
30	1572	898	852	557	948	590	1095
40	1335	877	895	605	1105	619	1101
50	1215	857	921	618	1163	692	1092
75	1074	823	953	670	1209	745	1258
100	1007	823	963	767	1239	813	1238
150	935	805	993	871	1149	781	1140
200	944	779	984	889	1110	875	1183



Description:	Here provide	**Fix k&c for comparison**	, represent the case without controling				
(Fixed damping ratio according to 390 kip/in, i.e. keep the same damping even in the range of 39 kip/in)							
(Different from the other columns, the 30% point means bilinear sys with 30% damping, no change in k&c.)							
The GV*BS,fy=50 column : when GV*BS is positive provide 20% damping according to390 kip/in(FIX)							
when GV*BS is negative provide c% damping according to 39 kip/in (VARY). The yield force of							
bilinear system is 50 kips.							
(30% point means when neg. GV*BS c=30% acc. to 39 kip/in; when pos. GV*BS c=20% acc. to 390 kip/in)							
KE + SE (Bilinear 390, 39) Fix stiff 20% (020.*)							
c(%)	Fix k&c	GV*BS,fy=50	GV*BS,fy=300	V*BS,fy=50	V*BS,fy=300	V*U,fy=50	V*U,fy=300
0	17288	1362	756	648	1025	676	1036
5	7689	1195	760	654	975	672	1030
9	4759	1060	767	640	952	658	999
15	2866	966	783	603	936	658	991
20	2171	893	799	625	929	665	978
25	1794	819	812	602	922	646	968
30	1572	718	820	603	904	651	952
40	1335	653	841	583	893	623	919
50	1215	608	852	579	866	597	886
75	1074	554	915	579	901	544	846
100	1007	540	1007	576	972	548	823
150	935	592	1105	591	1070	667	920
200	944	667	1147	587	1178	702	995



Description:

Here provide Fix k&c for comparison, represent the case without controling.

(Fixed damping ratio and stiffness to 390 kip/in. Different from the other columns.)

(The 30% point means the system has k=390 kip/in, c=30% critical damping; i.e. SDFS without control.)

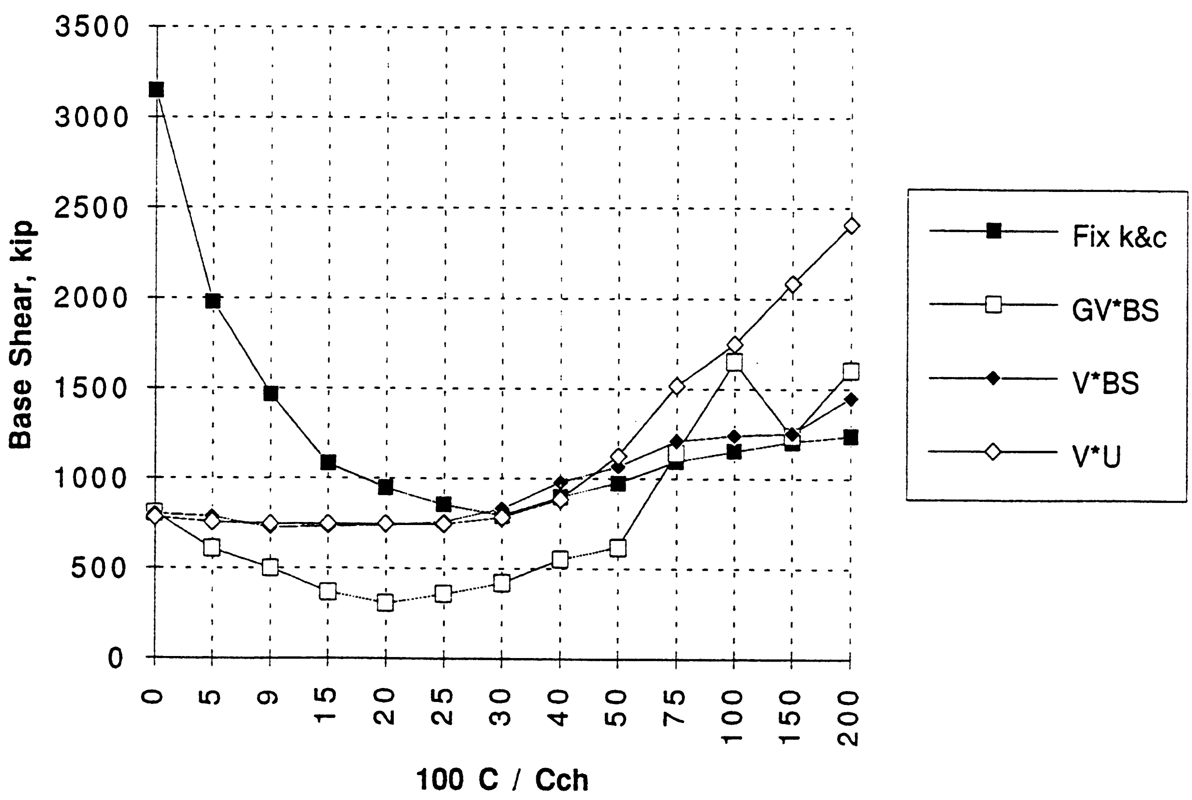
The V*BS(change) column: when V*BS is negative use k=39 kip/in, and c=5% acc. to 39 (FIX);

when V*BS is positive use k=390 kip/in, and c=c% acc. to 390. (VARY)

(The 30% point means when V*BS neg. k=39kip/in, c=5%; when pos. k=390kip/in, c=30%)

Base shear (Two stiffness 390, 39) Fix soft 5% (*.005)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	3144	809	800	781
5	1976	609	785	753
9	1465	501	725	746
15	1081	368	732	747
20	945	303	740	748
25	854	359	758	747
30	791	419	829	781
40	894	549	977	883
50	974	620	1065	1127
75	1095	1143	1209	1517
100	1154	1649	1238	1748
150	1205	1235	1251	2078
200	1235	1603	1449	2407



Description:

Here provide Fix k&c for comparison, represent the case without controling.

(Fixed damping ratio and stiffness to 390 kip/in. Different from the other columns.)

(The 30% point means the system has k=390 kip/in, c=30% critical damping; i.e. SDFS without control.)

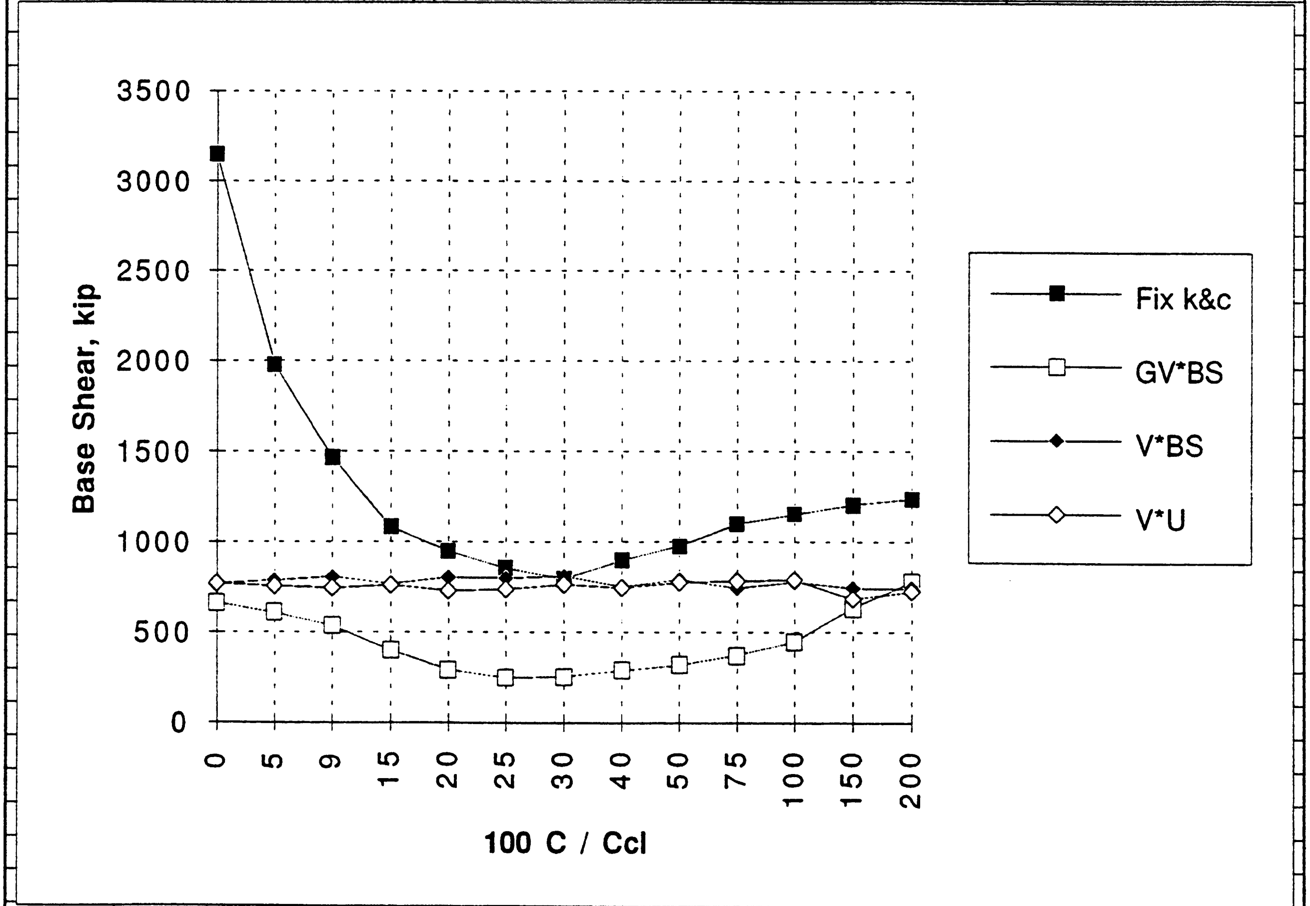
The V*BS(change) column: when V*BS is negative use k=39 kip/in, and c=c% acc. to 39 (VARY)

when V*BS is positive use k=390 kip/in, and c=5% acc. to 390. (FIX)

(The 30% point means when V*BS neg. k=39kip/in, c=30%; when pos. k=390kip/in, c=5%)

Base shear (Two stiffness 390, 39) Fix stiff 5% (005.*)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	3144	661.5	769	769
5	1976	608.7	785	753
9	1465	535.9	805	743
15	1081	400.5	765	757
20	945	292.3	801	728
25	854	249.7	795	737
30	791	256.5	808	762
40	894	290.4	752	745
50	974	318.4	788	773
75	1095	371.6	743	780
100	1154	448.3	777	788
150	1205	632.8	742	684
200	1235	779.4	742	724



Description:

Here provide Fix k&c for comparison, represent the case without controling.

(Fixed damping ratio and stiffness to 390 kip/in. Different from the other columns.)

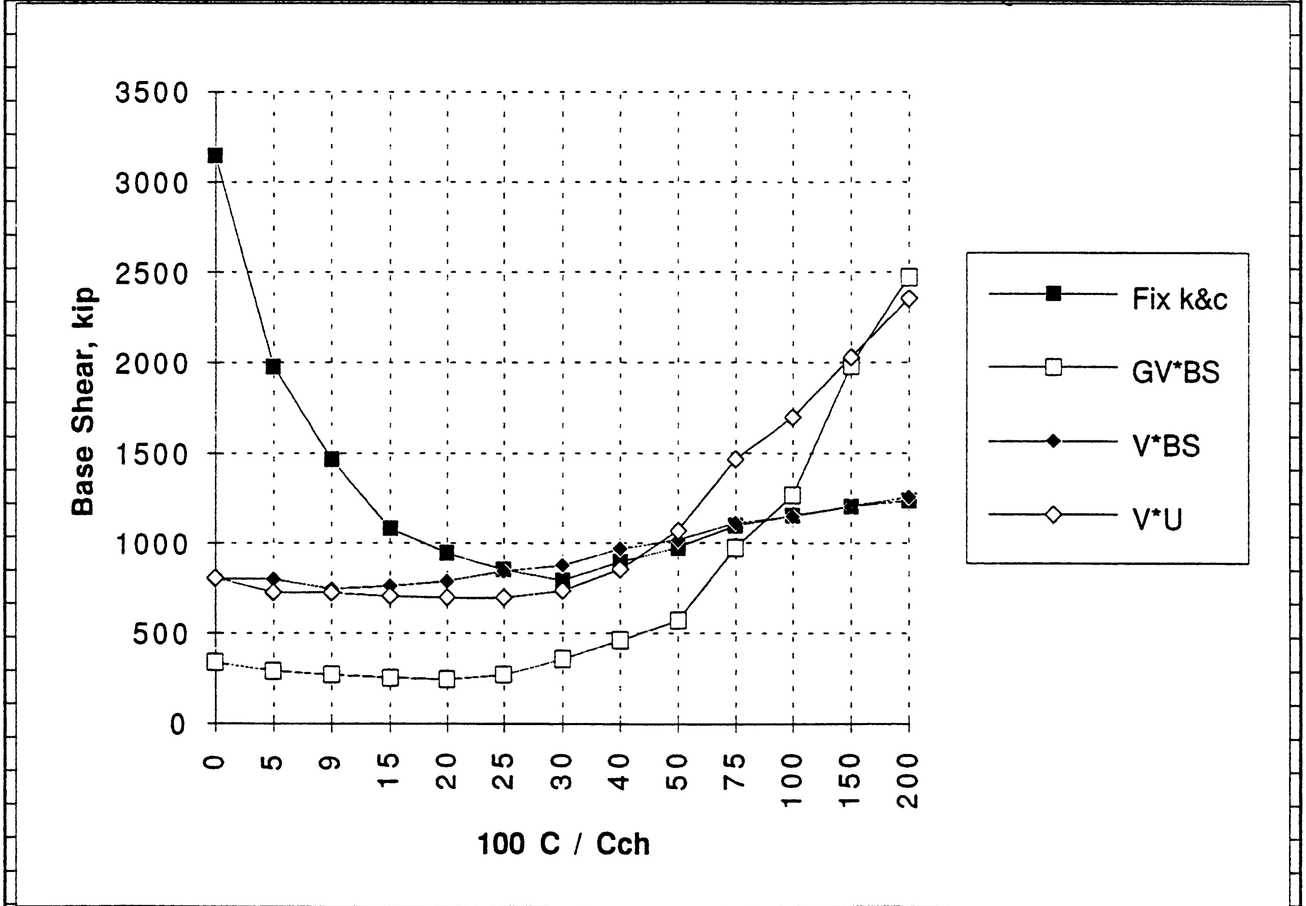
(The 30% point means the system has k=390 kip/in, c=30% critical damping; i.e. SDFS without control.)

The V*BS(change) column: when V*BS is negative use k=39 kip/in, and c=20% acc. to 39 (FIX); when V*BS is positive use k=390 kip/in, and c=c% acc. to 390. (VARY)

(The 30% point means when V*BS neg. k=39kip/in, c=20%; when pos. k=390kip/in, c=30%)

Base shear (Two stiffness 390, 39) Fix soft 20% (*.020)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	3144	338.5	803	806
5	1976	292.3	801	728
9	1465	271.6	747	724
15	1081	255.8	761	707
20	945	245.5	790	698
25	854	271.3	844	700
30	791	355.8	877	737
40	894	461.1	969	853
50	974	568.8	1017	1068
75	1095	975.8	1110	1467
100	1154	1267.4	1147	1696
150	1205	1981.1	1204	2028
200	1235	2472	1254	2353



Description:

Here provide Fix k&c for comparison, represent the case without controling.

(Fixed damping ratio and stiffness to 390 kip/in. Different from the other columns.)

(The 30% point means the system has k=390 kip/in, c=30% critical damping; i.e. SDFS without control.)

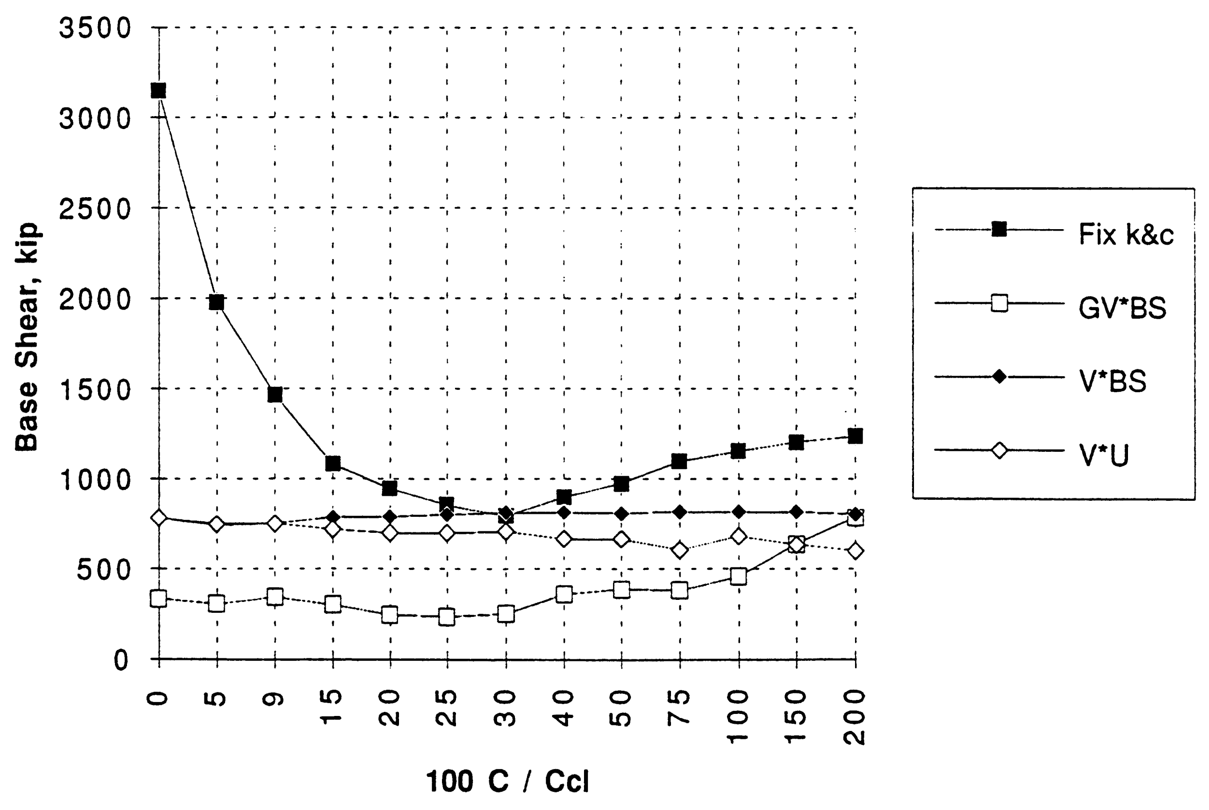
The V*BS(change) column: when V*BS is negative use k=39 kip/in, and c=c% acc. to 39 (VARY);

when V*BS is positive use k=390 kip/in, and c=20% acc. to 390. (FIX)

(The 30% point means when V*BS neg. k=39kip/in, c=30%; when pos. k=390kip/in, c=20%)

Base shear (Two stiffness 390, 39) Fix stiff 20% (020.*)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	3144	335.7	781	781
5	1976	302.8	740	748
9	1465	341.7	750	752
15	1081	300.2	785	719
20	945	245.5	790	698
25	854	234.3	799	697
30	791	252.3	812	707
40	894	358.4	812	663
50	974	388.3	808	664
75	1095	378.6	816	603
100	1154	455.3	817	678
150	1205	638.8	816	633
200	1235	783.6	804	598



Description:

Here provide Fix k&c for comparison, represent the case without controling.

(Fixed damping ratio and stiffness to 390 kip/in. Different from the other columns.)

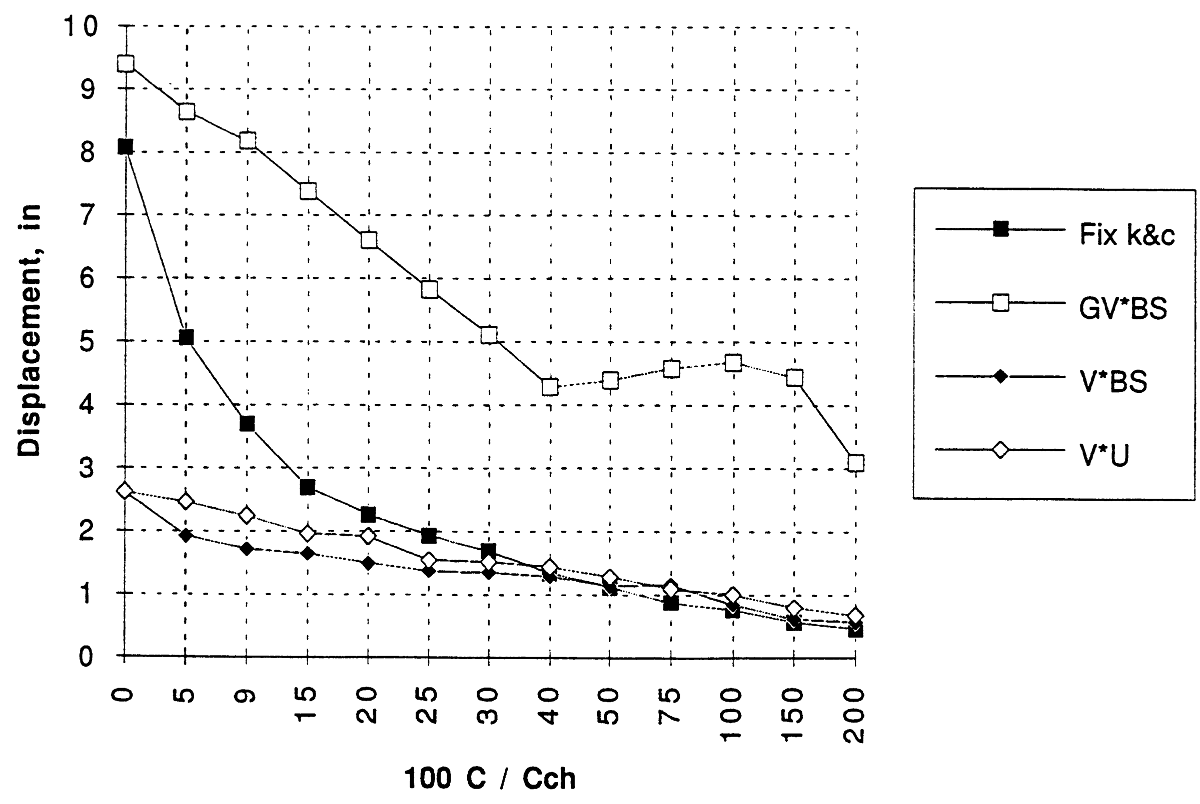
(The 30% point means the system has k=390 kip/in, c=30% critical damping; i.e. SDFS without control.)

The V*BS(change) column: when V*BS is negative use k=39 kip/in, and c=5% acc. to 39 (FIX);
when V*BS is positive use k=390 kip/in, and c=c% acc. to 390. (VARY)

(The 30% point means when V*BS neg. k=39kip/in, c=5%; when pos. k=390kip/in, c=30%)

Displacement (Two stiffness 390, 39) Fix soft 5% (*.005)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	8.06	9.391	2.596	2.615
5	5.041	8.631	1.918	2.451
9	3.682	8.175	1.715	2.236
15	2.683	7.366	1.639	1.953
20	2.259	6.591	1.486	1.911
25	1.935	5.818	1.369	1.541
30	1.684	5.11	1.341	1.508
40	1.33	4.275	1.285	1.432
50	1.119	4.383	1.125	1.279
75	0.876	4.578	1.147	1.087
100	0.747	4.677	0.838	0.994
150	0.572	4.442	0.615	0.794
200	0.456	3.09	0.561	0.662



Description:

Here provide Fix k&c for comparison, represent the case without controling.

(Fixed damping ratio and stiffness to 390 kip/in. Different from the other columns.)

(The 30% point means the system has k=390 kip/in, c=30% critical damping; i.e. SDFS without control.)

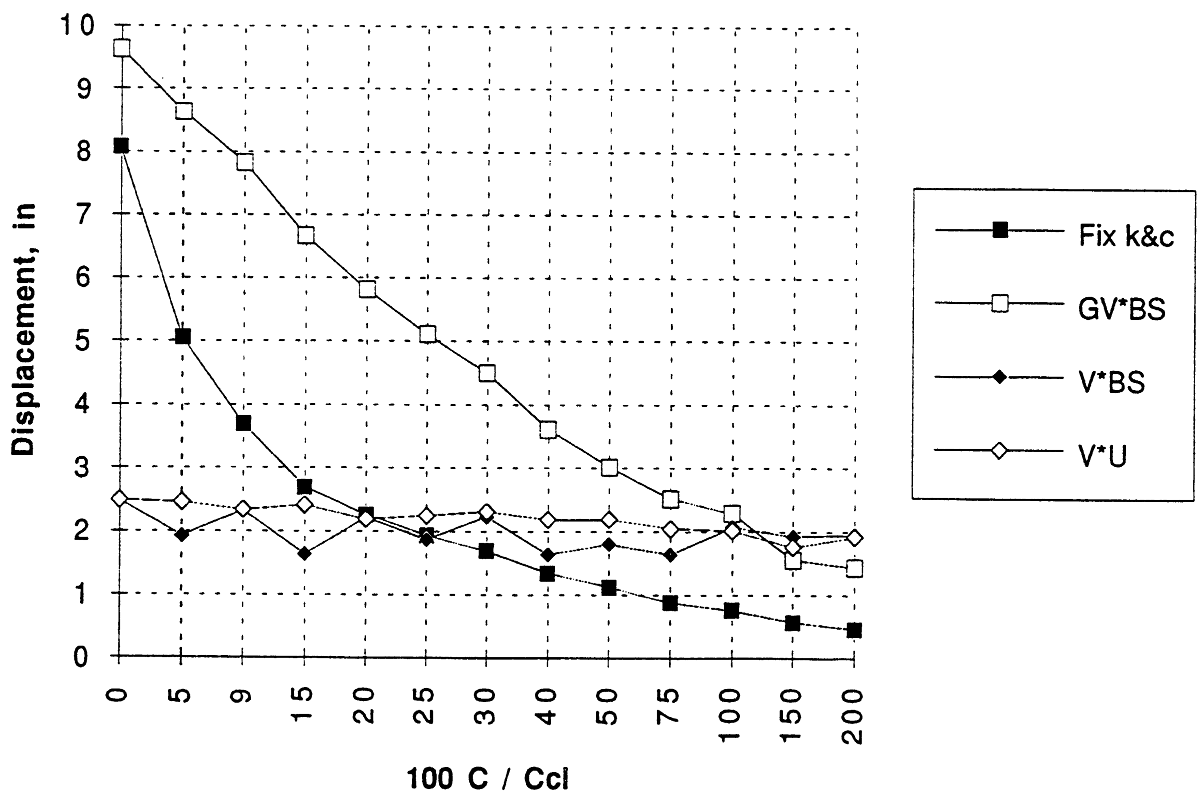
The V*BS(change) column: when V*BS is negative use k=39 kip/in, and c=c% acc. to 39 (VARY);

when V*BS is positive use k=390 kip/in, and c=5% acc. to 390. (FIX)

(The 30% point means when V*BS neg. k=39kip/in, c=30%; when pos. k=390kip/in, c=5%)

Displacement (Two stiffness 390, 39) Fix stiff 5% (005.*)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	8.06	9.615	2.479	2.48
5	5.041	8.631	1.918	2.451
9	3.682	7.826	2.319	2.329
15	2.683	6.66	1.627	2.4
20	2.259	5.804	2.2	2.176
25	1.935	5.097	1.866	2.245
30	1.684	4.489	2.218	2.306
40	1.33	3.604	1.627	2.174
50	1.119	3.007	1.794	2.182
75	0.876	2.508	1.627	2.04
100	0.747	2.28	2.059	2.009
150	0.572	1.556	1.914	1.743
200	0.456	1.424	1.941	1.912



Description:

Here provide Fix k&c for comparison, represent the case without controling.

(Fixed damping ratio and stiffness to 390 kip/in. Different from the other columns.)

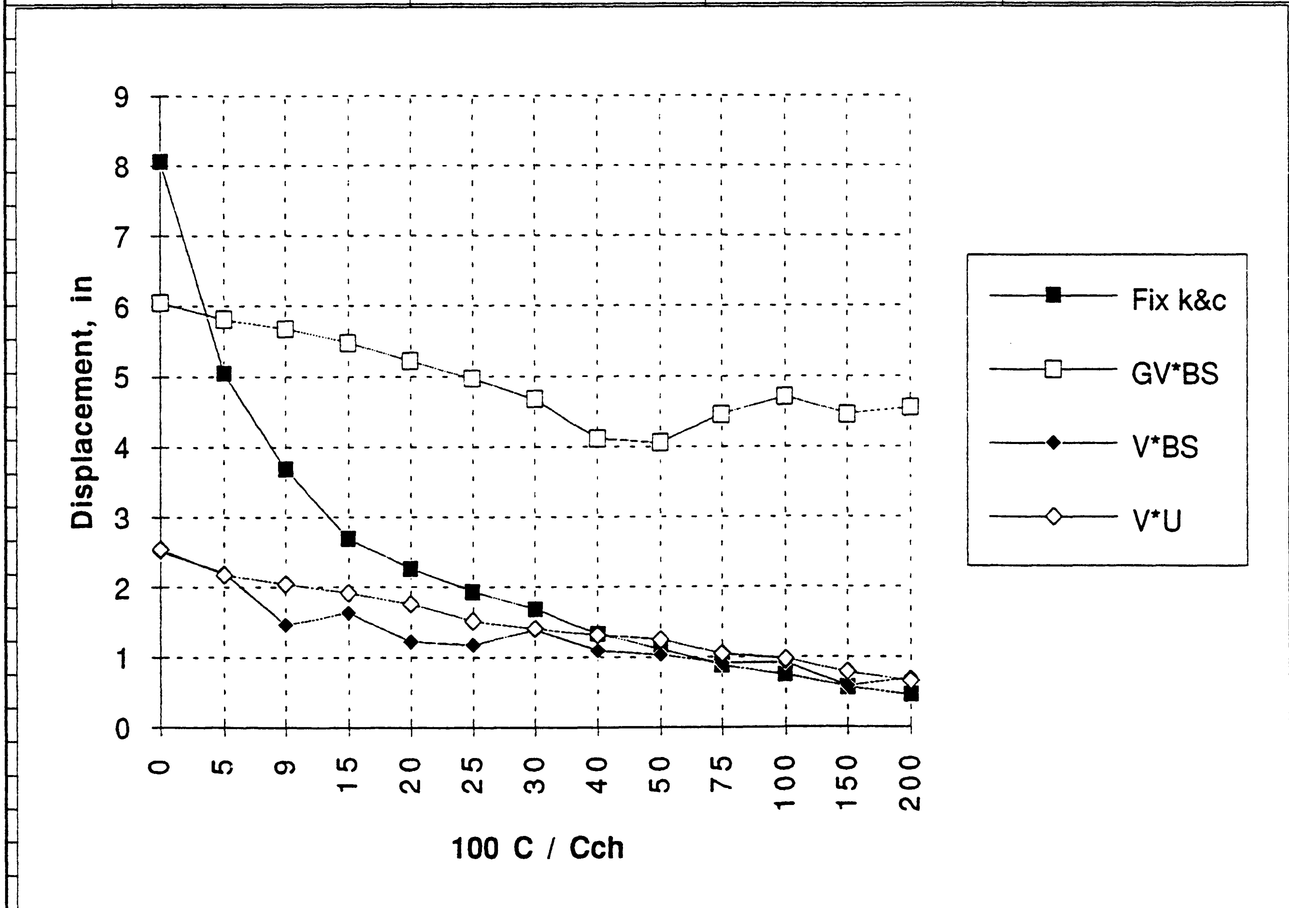
(The 30% point means the system has k=390 kip/in, c=30% critical damping; i.e. SDFS without control.)

The V*BS(change) column: when V*BS is negative use k=39 kip/in, and c=20% acc. to 39 (FIX);
when V*BS is positive use k=390 kip/in, and c=c% acc. to 390. (VARY)

(The 30% point means when V*BS neg. k=39kip/in, c=20%; when pos. k=390kip/in, c=30%)

Displacement (Two stiffness 390, 39) Fix soft 20% (*.020)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	8.06	6.037	2.492	2.535
5	5.041	5.804	2.2	2.176
9	3.682	5.679	1.469	2.035
15	2.683	5.472	1.631	1.91
20	2.259	5.214	1.218	1.753
25	1.935	4.957	1.171	1.516
30	1.684	4.669	1.385	1.411
40	1.33	4.103	1.097	1.311
50	1.119	4.041	1.023	1.254
75	0.876	4.45	0.91	1.048
100	0.747	4.705	0.919	0.973
150	0.572	4.452	0.582	0.781
200	0.456	4.536	0.698	0.647



Description:

Here provide Fix k&c for comparison, represent the case without controling.

(Fixed damping ratio and stiffness to 390 kip/in. Different from the other columns.)

(The 30% point means the system has k=390 kip/in, c=30% critical damping; i.e. SDFS without control.)

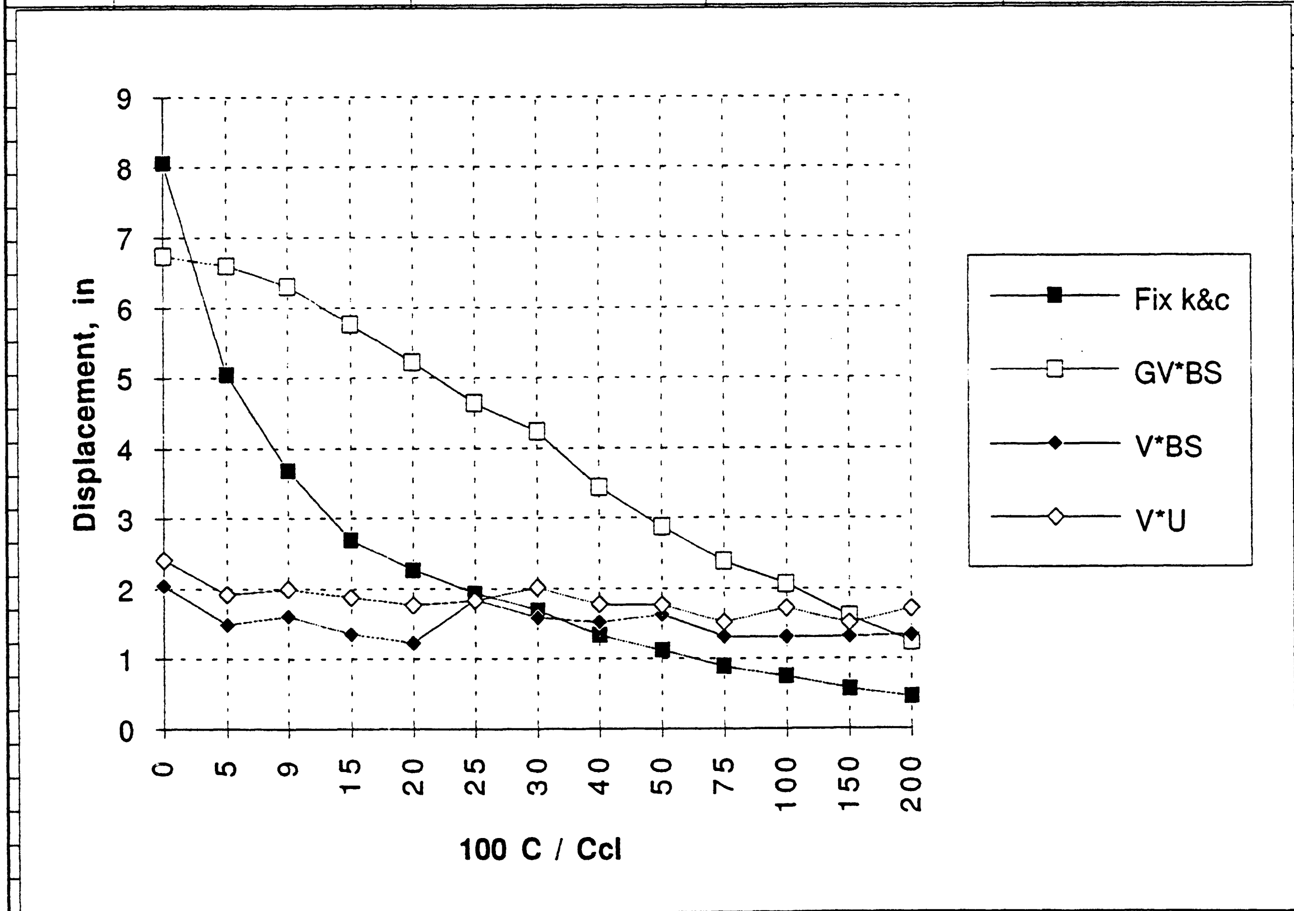
The V*BS(change) column: when V*BS is negative use k=39 kip/in, and c=c% acc. to 39 (VARY)

when V*BS is positive use k=390 kip/in, and c=20% acc. to 390. (FIX)

(The 30% point means when V*BS neg. k=39kip/in, c=30%; when pos. k=390kip/in, c=20%)

Displacement (Two stiffness 390, 39) Fix stiff 20% (020.*)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	8.06	6.733	2.038	2.404
5	5.041	6.591	1.486	1.911
9	3.682	6.302	1.6	1.99
15	2.683	5.755	1.352	1.874
20	2.259	5.214	1.218	1.753
25	1.935	4.632	1.83	1.828
30	1.684	4.232	1.583	2.009
40	1.33	3.441	1.509	1.765
50	1.119	2.867	1.62	1.76
75	0.876	2.383	1.305	1.518
100	0.747	2.07	1.306	1.715
150	0.572	1.6	1.305	1.5
200	0.456	1.24	1.34	1.712



Description:

Here provide Fix k&c for comparison, represent the case without controling.

(Fixed damping ratio and stiffness to 390 kip/in. Different from the other columns.)

(The 30% point means the system has k=390 kip/in, c=30% critical damping; i.e. SDFS without control.)

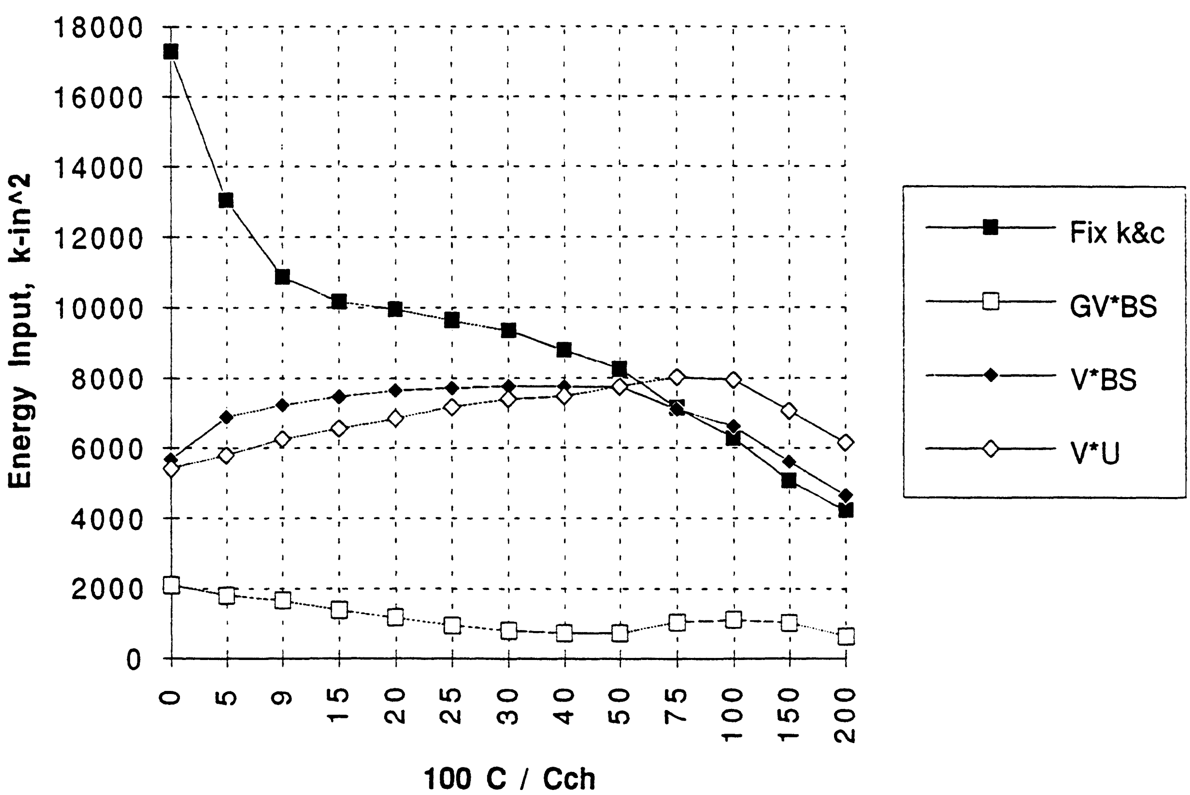
The V*BS(change) column: when V*BS is negative use k=39 kip/in, and c=5% acc. to 39 (FIX);

when V*BS is positive use k=390 kip/in, and c=c% acc. to 390. (VARY)

(The 30% point means when V*BS neg. k=39kip/in, c=5%; when pos. k=390kip/in, c=30%)

Energy Input (Two stiffness 390, 39) Fix soft 5% (*.005)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	17288	2089	5654	5397
5	13023	1796	6885	5795
9	10868	1638	7207	6248
15	10150	1380	7472	6541
20	9937	1150	7643	6841
25	9634	946	7703	7172
30	9326	782	7758	7377
40	8759	730	7743	7470
50	8237	715	7731	7735
75	7138	1045	7089	8003
100	6277	1099	6613	7938
150	5042	1027	5590	7062
200	4210	638	4637	6133



Description:

Here provide Fix k&c for comparison, represent the case without controling.

(Fixed damping ratio and stiffness to 390 kip/in. Different from the other columns.)

(The 30% point means the system has k=390 kip/in, c=30% critical damping; i.e. SDFS without control.)

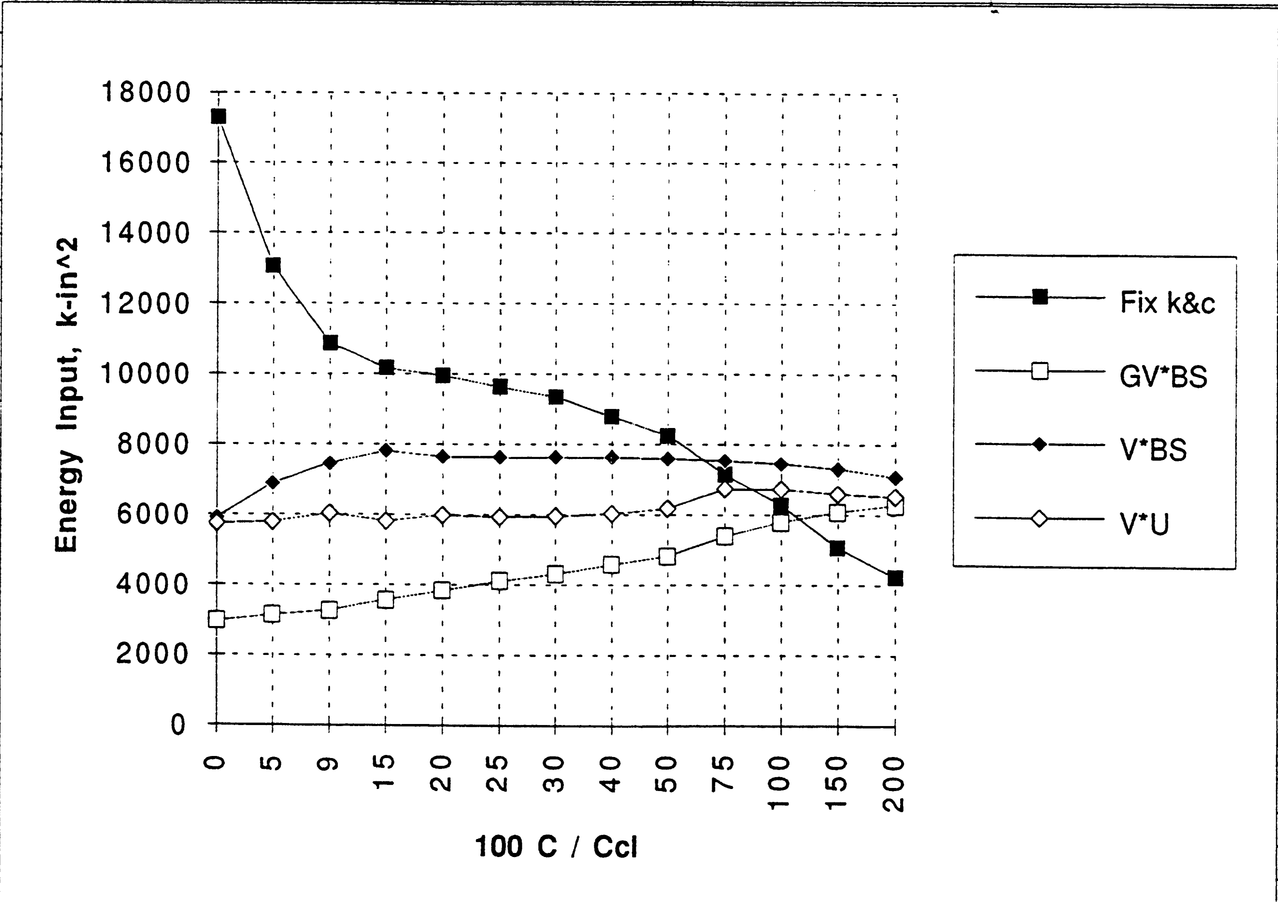
The V*BS(change) column: when V*BS is negative use k=39 kip/in, and c=c% acc. to 39 (VARY)

when V*BS is positive use k=390 kip/in, and c=5% acc. to 390. (FIX)

(The 30% point means when V*BS neg. k=39kip/in, c=30%; when pos. k=390kip/in, c=5%)

Energy Input (Two stiffness 390, 39) Fix stiff 5% (005.*)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	17288	2945	5898	5727
5	13023	3120	6885	5795
9	10868	3260	7444	6014
15	10150	3541	7788	5809
20	9937	3819	7639	5982
25	9634	4093	7624	5922
30	9326	4289	7615	5956
40	8759	4562	7626	6030
50	8237	4816	7580	6180
75	7138	5377	7518	6723
100	6277	5788	7435	6722
150	5042	6089	7283	6593
200	4210	6282	7082	6516



Description:

Here provide Fix k&c for comparison, represent the case without controling.

(Fixed damping ratio and stiffness to 390 kip/in. Different from the other columns.)

(The 30% point means the system has k=390 kip/in, c=30% critical damping; i.e. SDFS without control.)

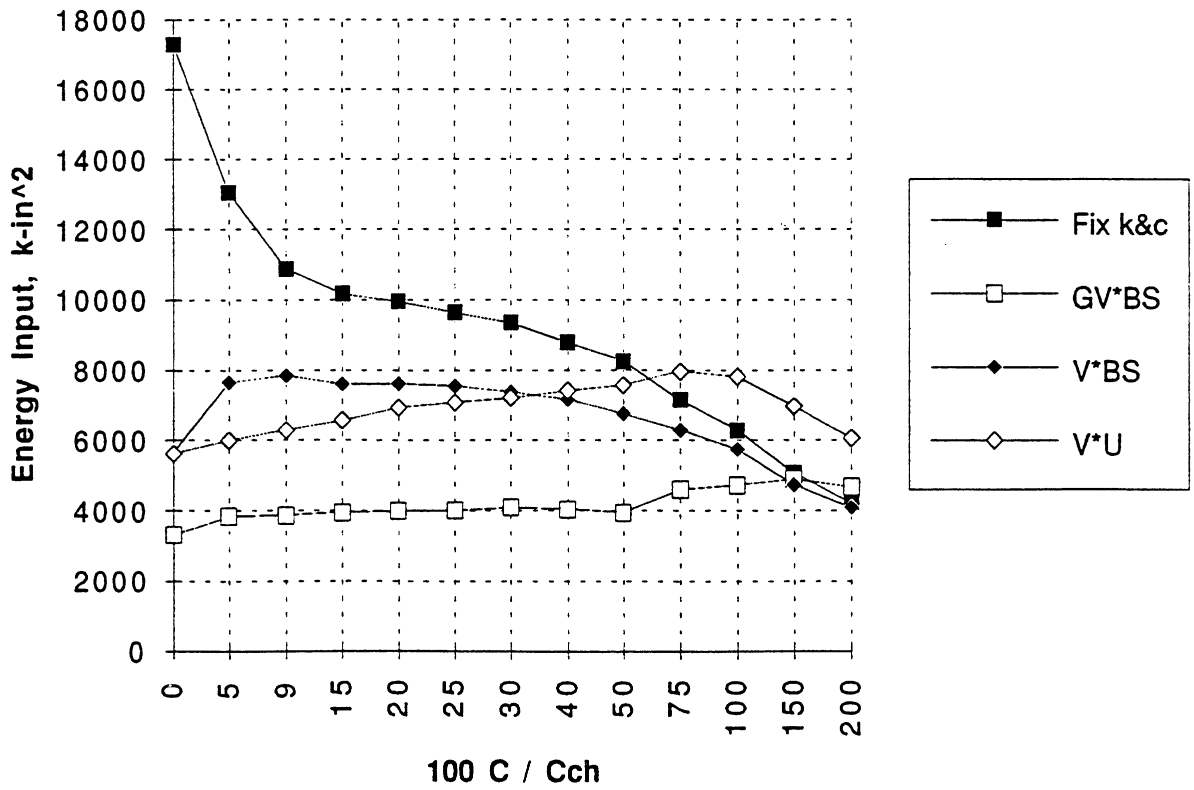
The V*BS(change) column: when V*BS is negative use k=39 kip/in, and c=20% acc. to 39 (FIX);

when V*BS is positive use k=390 kip/in, and c=c% acc. to 390. (VARY)

(The 30% point means when V*BS neg. k=39kip/in, c=20%; when pos. k=390kip/in, c=30%)

Energy Input (Two stiffness 390, 39) Fix soft 20% (*.020)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	17288	3289	5634	5622
5	13023	3819	7639	5981
9	10868	3870	7839	6270
15	10150	3932	7589	6547
20	9937	3975	7601	6912
25	9634	3999	7543	7067
30	9326	4077	7358	7199
40	8759	4032	7152	7407
50	8237	3941	6744	7568
75	7138	4582	6265	7940
100	6277	4709	5722	7794
150	5042	4873	4709	6965
200	4210	4671	4085	6042



Description:

Here provide Fix k&c for comparison, represent the case without controling.

(Fixed damping ratio and stiffness to 390 kip/in. Different from the other columns.)

(The 30% point means the system has k=390 kip/in, c=30% critical damping; i.e. SDFS without control.)

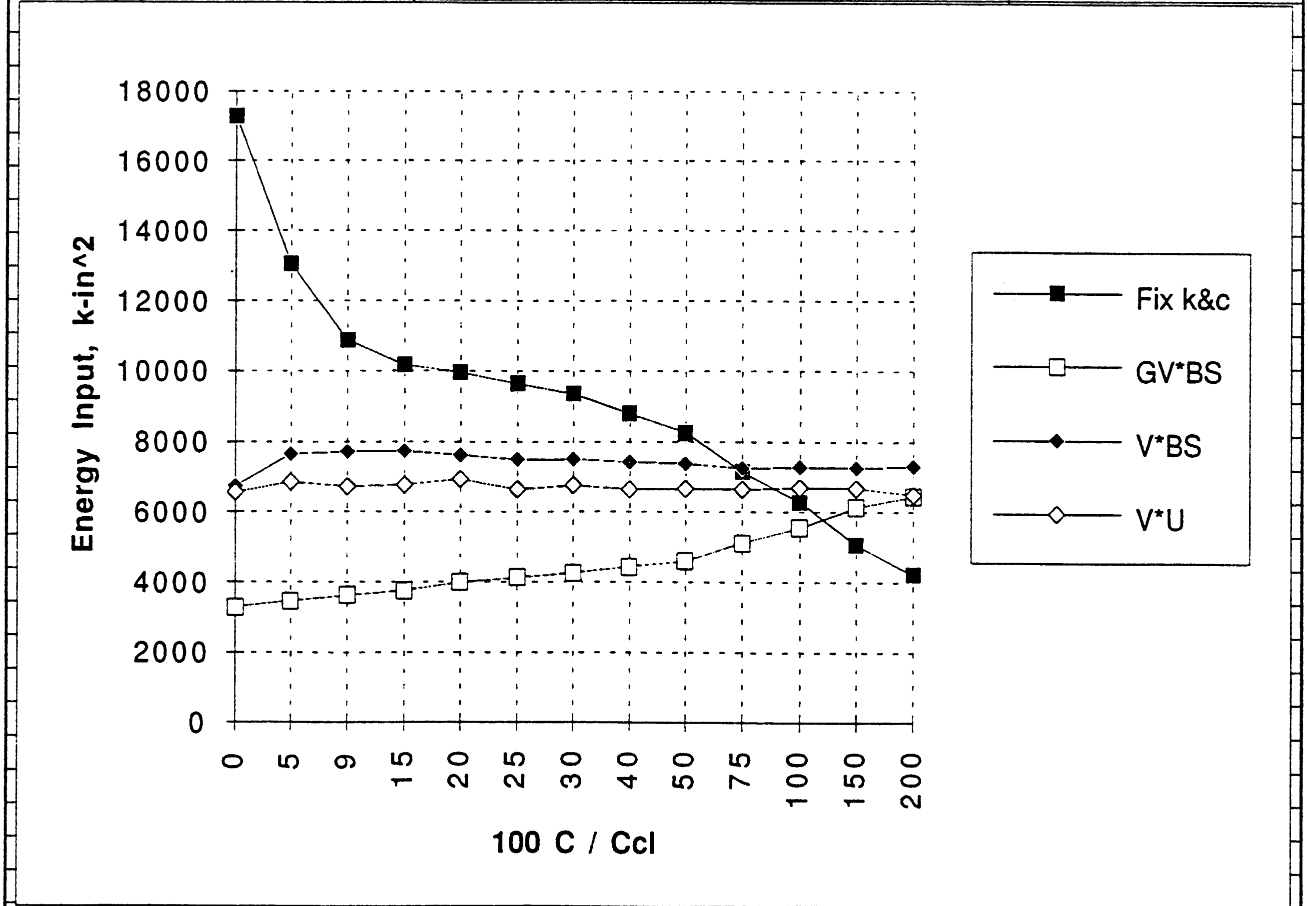
The V*BS(change) column: when V*BS is negative use k=39 kip/in, and c=c% acc. to 39 (VARY)

when V*BS is positive use k=390 kip/in, and c=20% acc. to 390. (FIX)

(The 30% point means when V*BS neg. k=39kip/in, c=30%; when pos. k=390kip/in, c=20%)

Energy Input (Two stiffness 390, 39) Fix stiff 20% (020.*)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	17288	3277	6721	6554
5	13023	3459	7643	6841
9	10868	3616	7697	6696
15	10150	3747	7716	6765
20	9937	3975	7601	6912
25	9634	4119	7492	6619
30	9326	4243	7479	6749
40	8759	4416	7400	6621
50	8237	4594	7365	6654
75	7138	5110	7229	6623
100	6277	5544	7267	6675
150	5042	6123	7239	6666
200	4210	6429	7283	6488



Description:

Here provide Fix k&c for comparison, represent the case without controling.

(Fixed damping ratio and stiffness to 390 kip/in. Different from the other columns.)

(The 30% point means the system has k=390 kip/in, c=30% critical damping; i.e. SDFS without control.)

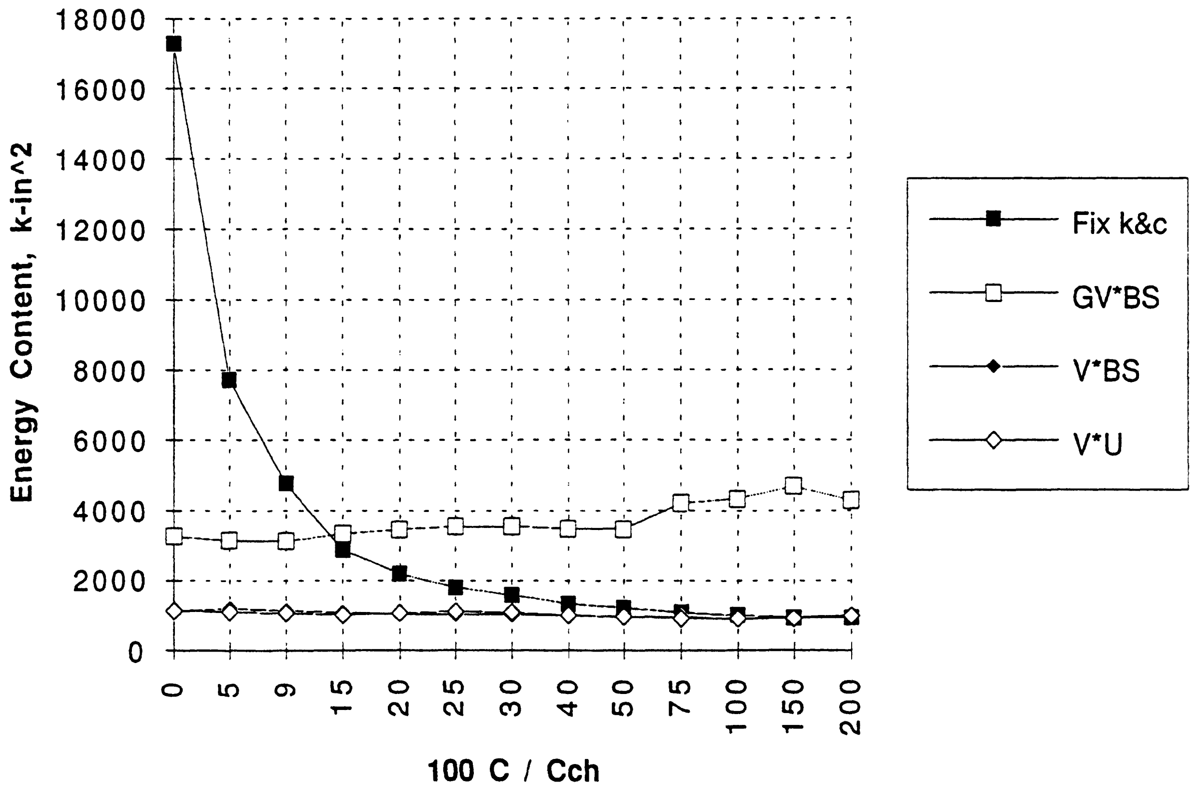
The V*BS(change) column: when V*BS is negative use k=39 kip/in, and c=5% acc. to 39 (FIX);

when V*BS is positive use k=390 kip/in, and c=c% acc. to 390. (VARY)

(The 30% point means when V*BS neg. k=39kip/in, c=5%; when pos. k=390kip/in, c=30%)

KE +SE (Two stiffness 390, 39) Fix soft 5% (*.005)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	17288	3239	1113	1130
5	7689	3120	1194	1094
9	4759	3099	1133	1055
15	2866	3326	1076	1019
20	2171	3459	1041	1055
25	1794	3530	1035	1110
30	1572	3534	1013	1078
40	1335	3471	1017	996
50	1215	3461	949	955
75	1074	4197	964	929
100	1007	4325	877	909
150	935	4682	948	917
200	944	4281	1007	974



Description:

Here provide Fix k&c for comparison, represent the case without controling.

(Fixed damping ratio and stiffness to 390 kip/in. Different from the other columns.)

(The 30% point means the system has k=390 kip/in, c=30% critical damping; i.e. SDFS without control.)

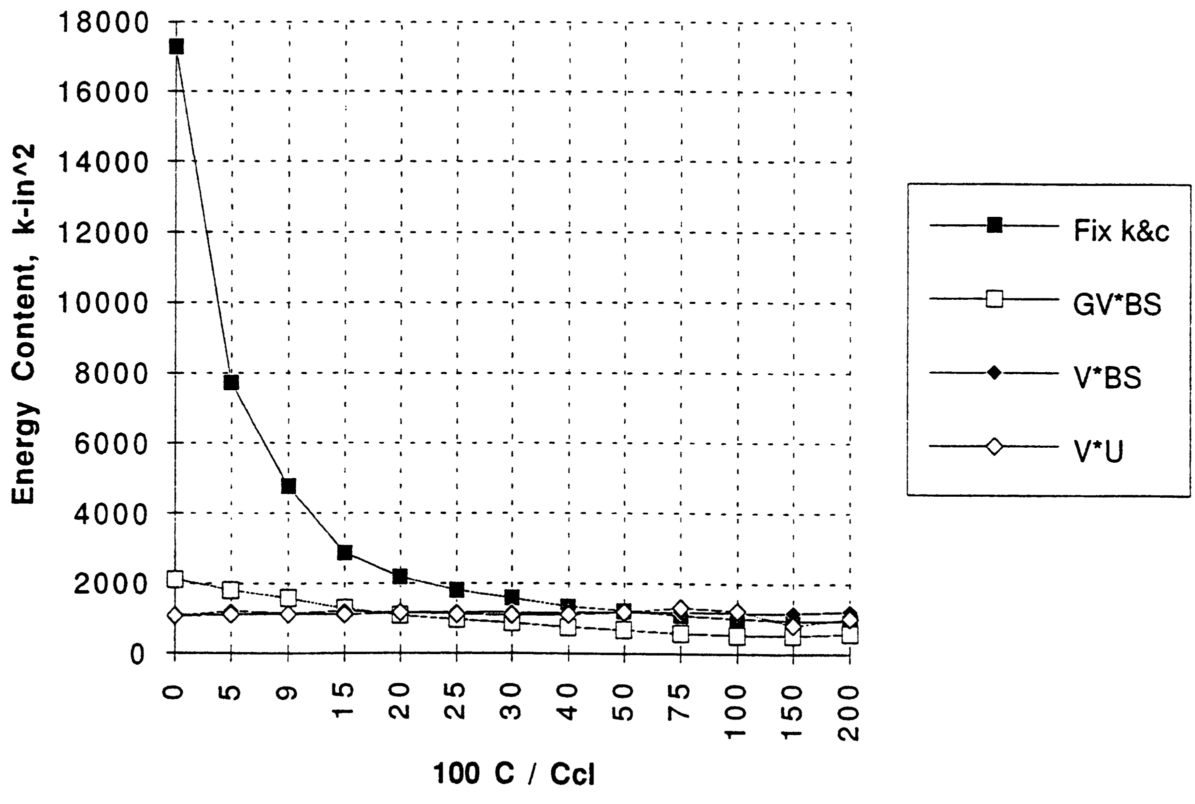
The V*BS(change) column: when V*BS is negative use k=39 kip/in, and c=c% acc. to 39 (VARY)

when V*BS is positive use k=390 kip/in, and c=5% acc. to 390. (FIX)

(The 30% point means when V*BS neg. k=39kip/in, c=30%; when pos. k=390kip/in, c=5%)

KE +SE (Two stiffness 390, 39) Fix stiff 5% (005.*)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	17288	2106	1068	1067
5	7689	1796	1194	1094
9	4759	1566	1144	1116
15	2866	1268	1203	1100
20	2171	1080	1159	1157
25	1794	957	1182	1117
30	1572	868	1165	1083
40	1335	750	1161	1103
50	1215	680	1182	1173
75	1074	569	1184	1298
100	1007	529	1164	1211
150	935	519	1150	800
200	944	581	1192	1000



Description:

Here provide Fix k&c for comparison, represent the case without controling.

(Fixed damping ratio and stiffness to 390 kip/in. Different from the other columns.)

(The 30% point means the system has k=390 kip/in, c=30% critical damping; i.e. SDFS without control.)

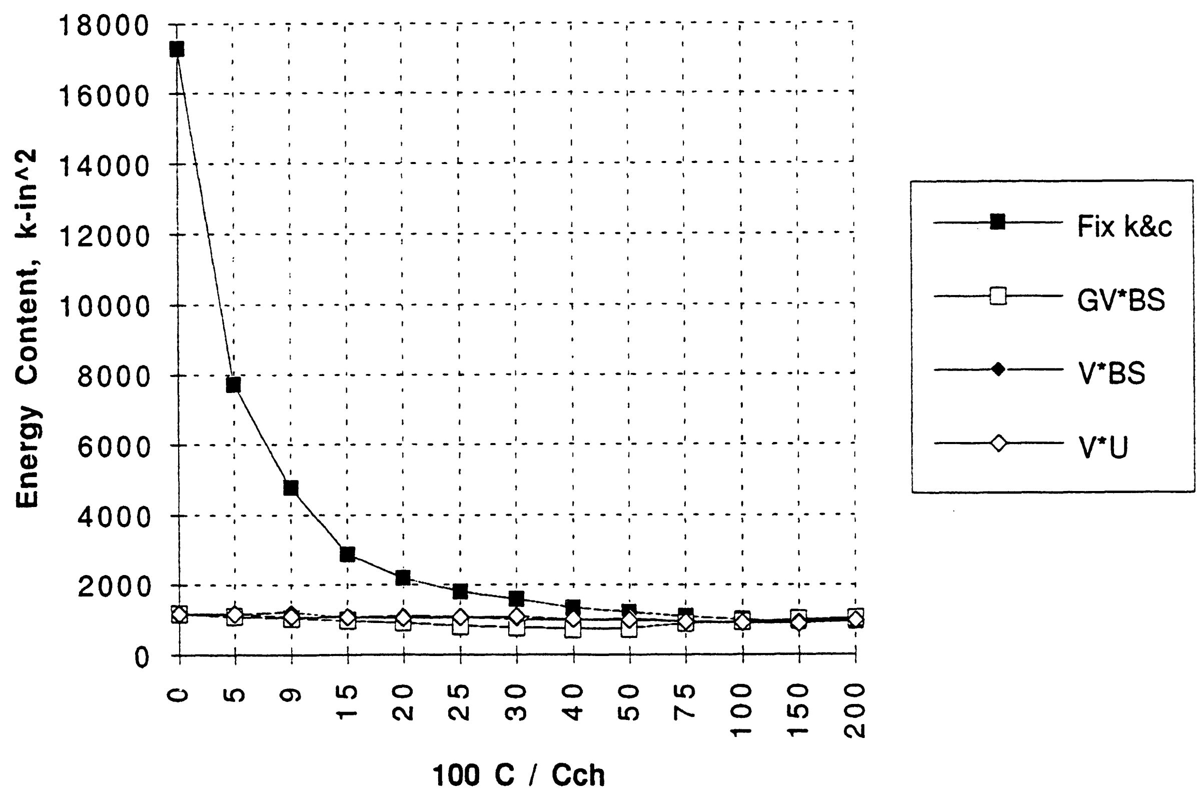
The V*BS(change) column: when V*BS is negative use k=39 kip/in, and c=20% acc. to 39 (FIX);

when V*BS is positive use k=390 kip/in, and c=c% acc. to 390. (VARY)

(The 30% point means when V*BS neg. k=39kip/in, c=20%; when pos. k=390kip/in, c=30%)

KE +SE (Two stiffness 390, 39) Fix soft 20% (*.020)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	17288	1160	1177	1160
5	7689	1080	1159	1157
9	4759	1037	1207	1072
15	2866	973	1061	1064
20	2171	900	1119	1033
25	1794	832	1081	1063
30	1572	762	1003	1081
40	1335	728	985	1004
50	1215	753	1035	975
75	1074	895	929	933
100	1007	939	922	907
150	935	1004	957	882
200	944	1044	1009	970



Description:

Here provide Fix k&c for comparison, represent the case without controling.

(Fixed damping ratio and stiffness to 390 kip/in. Different from the other columns.)

(The 30% point means the system has k=390 kip/in, c=30% critical damping; i.e. SDFS without control.)

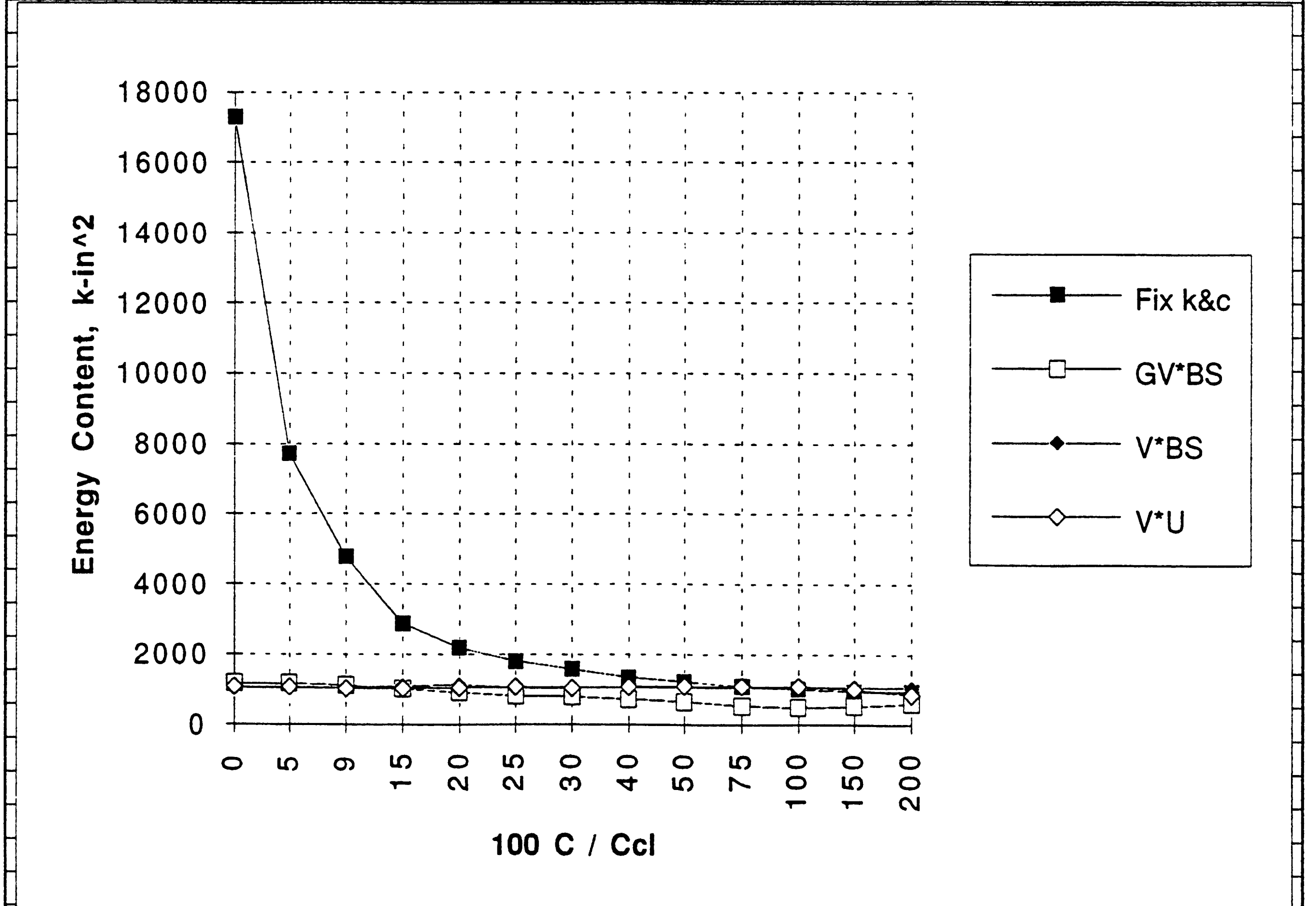
The V*BS(change) column: when V*BS is negative use k=39 kip/in, and c=c% acc. to 39 (VARY);

when V*BS is positive use k=390 kip/in, and c=20% acc. to 390. (FIX)

(The 30% point means when V*BS neg. k=39kip/in, c=30%; when pos. k=390kip/in, c=20%)

KE +SE (Two stiffness 390, 39) Fix stiff 20% (020.*)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	17288	1160	1046	1052
5	7689	1149	1041	1055
9	4759	1097	1041	1010
15	2866	996	1087	1018
20	2171	900	1119	1033
25	1794	807	1033	1053
30	1572	789	1042	1039
40	1335	711	1059	1070
50	1215	650	1050	1082
75	1074	531	1063	1077
100	1007	486	1062	1076
150	935	521	1065	1008
200	944	592	1042	852



Description:

Here the stiffness always the same 390 kip/in.

Here provide Fix k&c for comparison, represent the case without controling.

(Different from the other columns, the damping ratio is always the same)

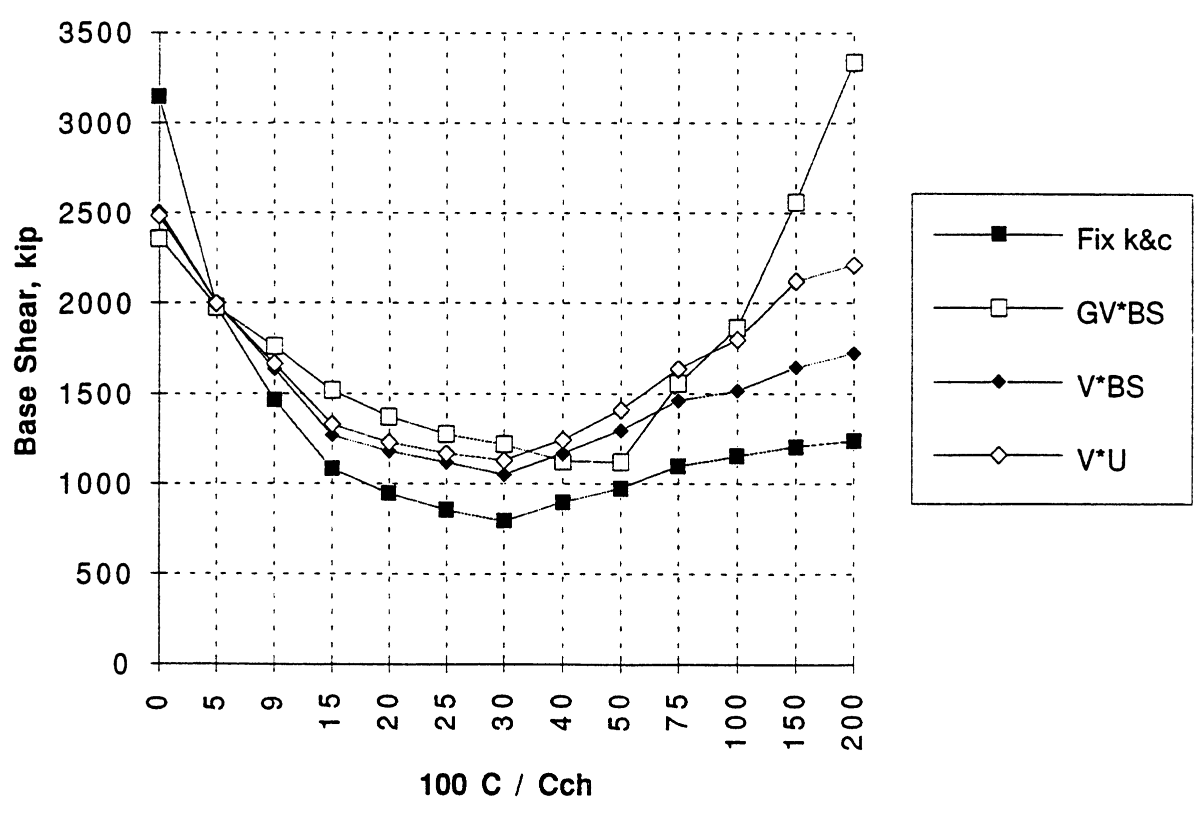
(The 30% point means the system has k=390 kip/in and c=30% critical. i.e. SDFS without control.)

The V*U(same) column: when V*U is negative c=5%(FIX); when positive c=c%(VARY).

(The 30% point means when V*U is neg. c=5%, k=390; when pos. c=30%, k=390.)

Base shear (Same stiffness 390) Fix soft 5% (*.005)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	3144	2357	2505	2481
5	1976	1976	1997	1997
9	1465	1757	1635	1664
15	1081	1517	1267	1325
20	945	1372	1180	1230
25	854	1274	1117	1168
30	791	1218	1051	1130
40	894	1124	1167	1242
50	974	1118	1295	1410
75	1095	1552	1460	1637
100	1154	1862	1515	1796
150	1205	2558	1645	2118
200	1235	3331	1720	2207



Description:

Here the stiffness always the same 390 kip/in.

Here provide Fix k&c for comparison, represent the case without controling.

(Different from the other columns, the damping ratio is always the same)

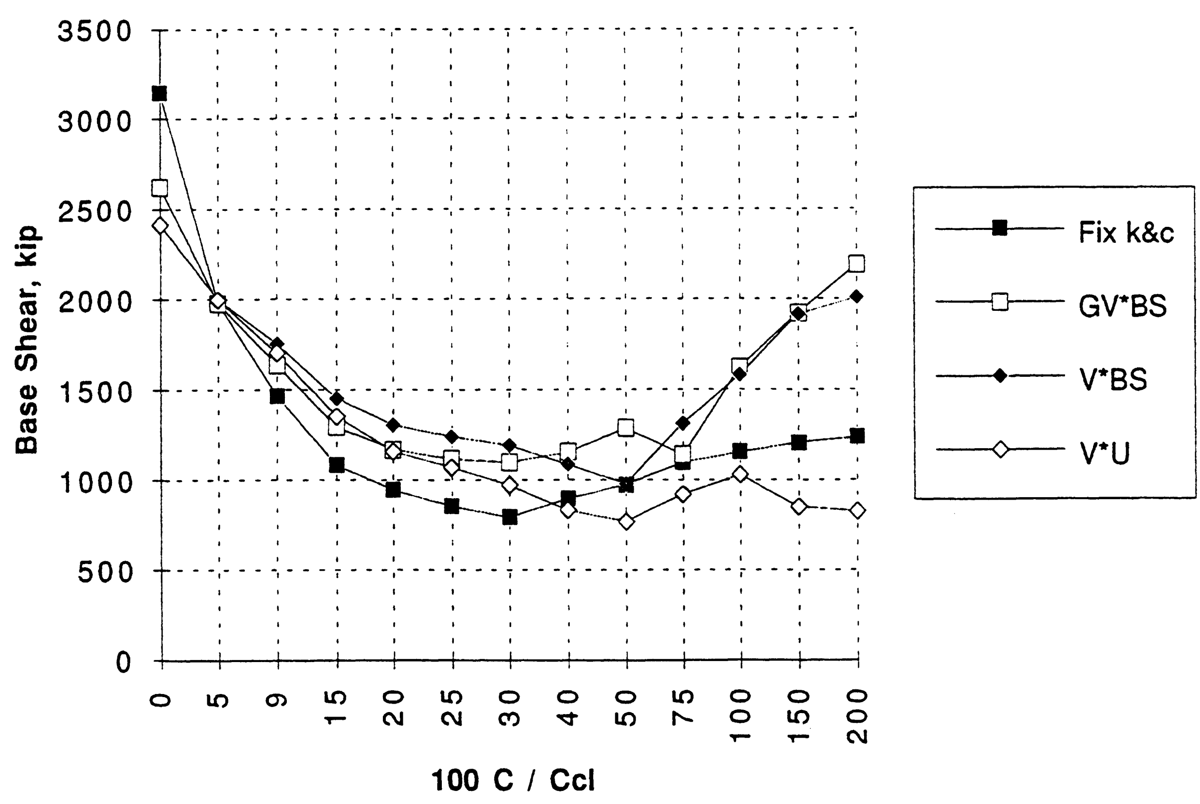
(The 30% point means the system has k=390 kip/in and c=30% critical. i.e. SDFS without control.)

The V*U(same) column: when V*U is negative c=c%(VARY); when positive c=5%(FIX).

(The 30% point means when V*U is neg. c=30%, k=390; when pos. c=5%, k=390.)

Base shear (Same stiffness 390) Fix stiff 5% (005.*)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	3144	2619	2413	2413
5	1976	1976	1997	1997
9	1465	1636	1752	1703
15	1081	1291	1450	1353
20	945	1166	1305	1158
25	854	1116	1238	1067
30	791	1096	1192	972
40	894	1151	1084	830
50	974	1285	977	768
75	1095	1138	1311	920
100	1154	1620	1581	1027
150	1205	1922	1912	848
200	1235	2191	2004	827



Description:

Here the stiffness always the same 390 kip/in.

Here provide Fix k&c for comparison, represent the case without controling.

(Different from the other columns, the damping ratio is always the same)

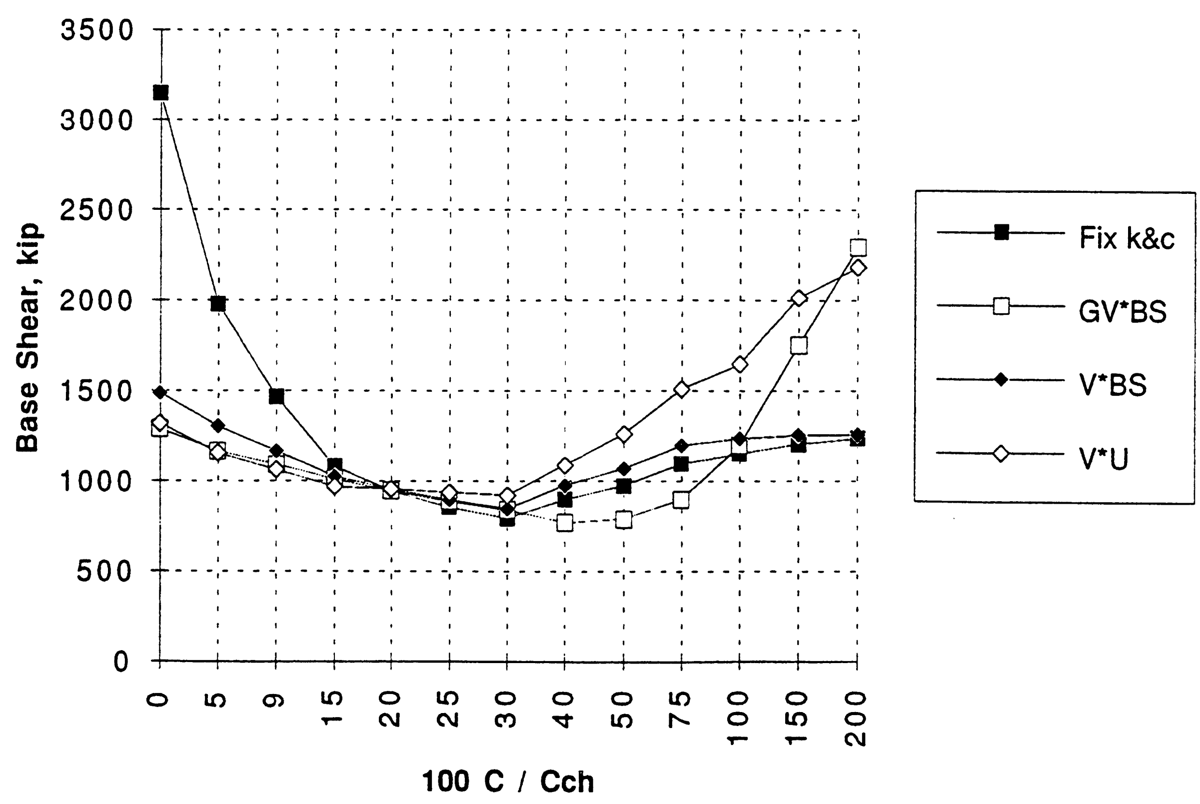
(The 30% point means the system has k=390 kip/in and c=30% critical. i.e. SDFS without control.)

The V*U(same) column: when V*U is negative c=20%(FIX); when positive c=c%(VARY).

(The 30% point means when V*U is neg. c=20%, k=390; when pos. c=30%, k=390.)

Base shear (Same stiffness 390) Fix soft 20% (*.020)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	3144	1289	1484	1318
5	1976	1166	1305	1158
9	1465	1092	1168	1061
15	1081	1008	1022	969
20	945	944	954	954
25	854	888	896	938
30	791	838	845	920
40	894	770	974	1086
50	974	788	1068	1261
75	1095	897	1198	1508
100	1154	1199	1236	1644
150	1205	1748	1256	2012
200	1235	2292	1257	2183



Description:

Here the stiffness always the same 390 kip/in.

Here provide Fix k&c for comparison, represent the case without controling.

(Different from the other columns, the damping ratio is always the same)

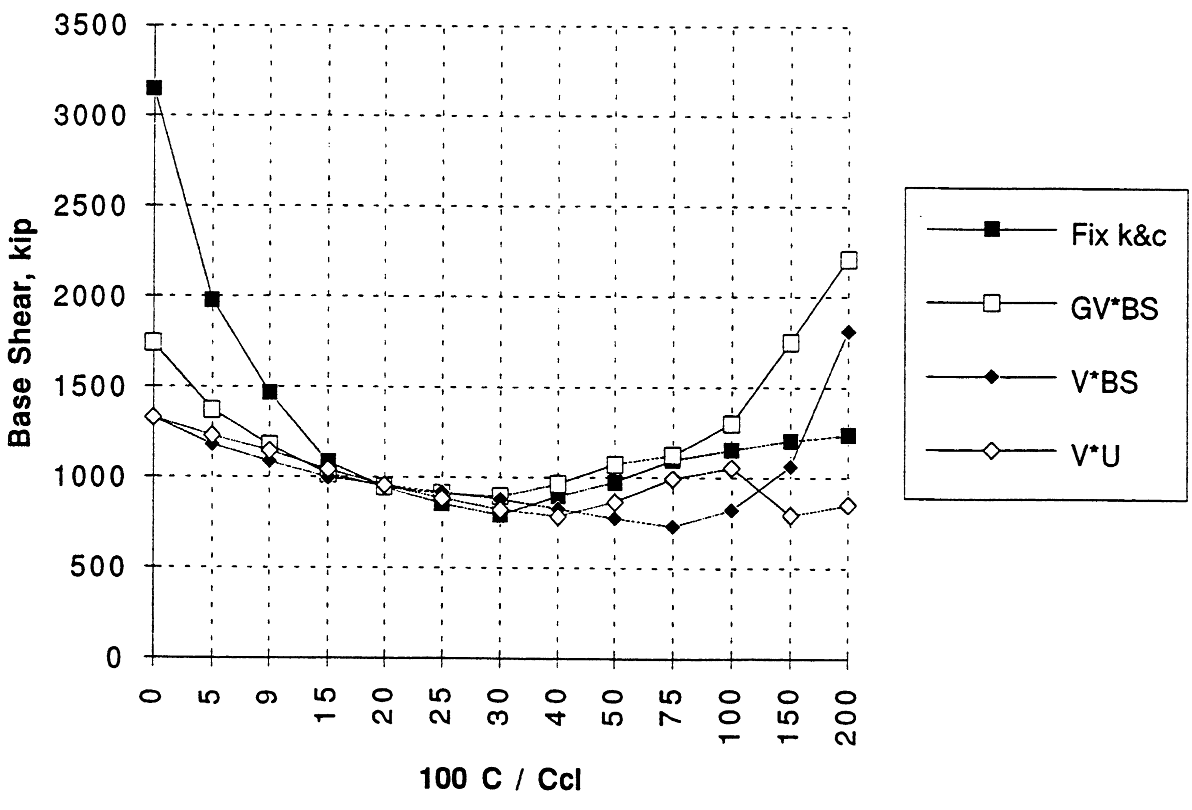
(The 30% point means the system has k=390 kip/in and c=30% critical. i.e. SDFS without control.)

The V*U(same) column: when V*U is negative c=c%(VARY); when positive c=20%(FIX).

(The 30% point means when V*U is neg. c=30%, k=390; when pos. c=20%, k=390.)

Base shear (Same stiffness 390) Fix stiff 20% (020.*)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	3144	1740	1325	1326
5	1976	1372	1180	1230
9	1465	1175	1085	1146
15	1081	1016	996	1038
20	945	944	954	954
25	854	910	918	883
30	791	894	879	821
40	894	964	826	784
50	974	1072	773	863
75	1095	1121	733	992
100	1154	1298	822	1054
150	1205	1750	1063	793
200	1235	2209	1809	848



Description:

Here the stiffness always the same 390 kip/in.

Here provide Fix k&c for comparison, represent the case without controling.

(Different from the other columns, the damping ratio is always the same)

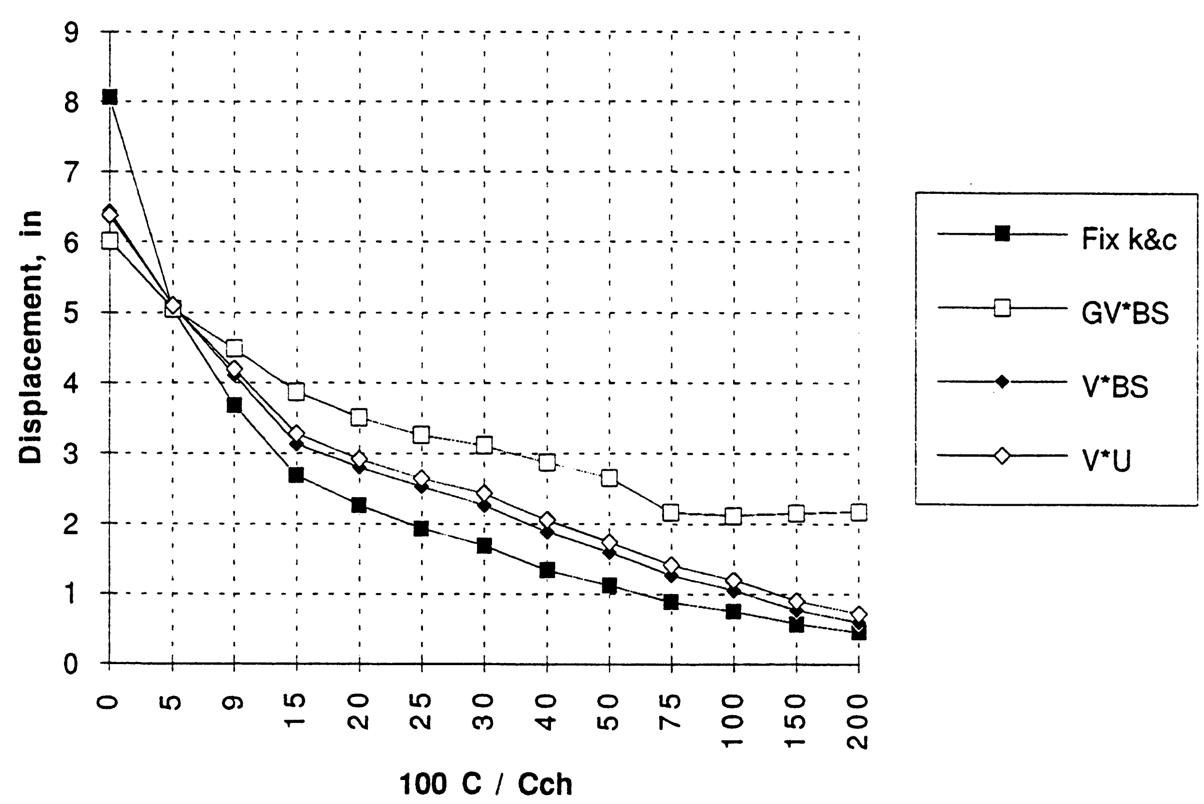
(The 30% point means the system has k=390 kip/in and c=30% critical. i.e. SDFS without control.)

The V*U(same) column: when V*U is negative c=5%(FIX); when positive c=c%(VARY).

(The 30% point means when V*U is neg. c=5%, k=390; when pos. c=30%, k=390.)

Displacement (Same stiffness 390) Fix soft 5% (*.005)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	8.06	6.012	6.431	6.365
5	5.041	5.041	5.094	5.095
9	3.682	4.48	4.112	4.187
15	2.683	3.868	3.13	3.278
20	2.259	3.5	2.798	2.916
25	1.935	3.253	2.526	2.639
30	1.684	3.111	2.257	2.427
40	1.33	2.87	1.88	2.047
50	1.119	2.646	1.593	1.74
75	0.876	2.157	1.259	1.407
100	0.747	2.119	1.049	1.189
150	0.572	2.151	0.764	0.899
200	0.456	2.175	0.594	0.719



Description:

Here the stiffness always the same 390 kip/in.

Here provide Fix k&c for comparison, represent the case without controling.

(Different from the other columns, the damping ratio is always the same)

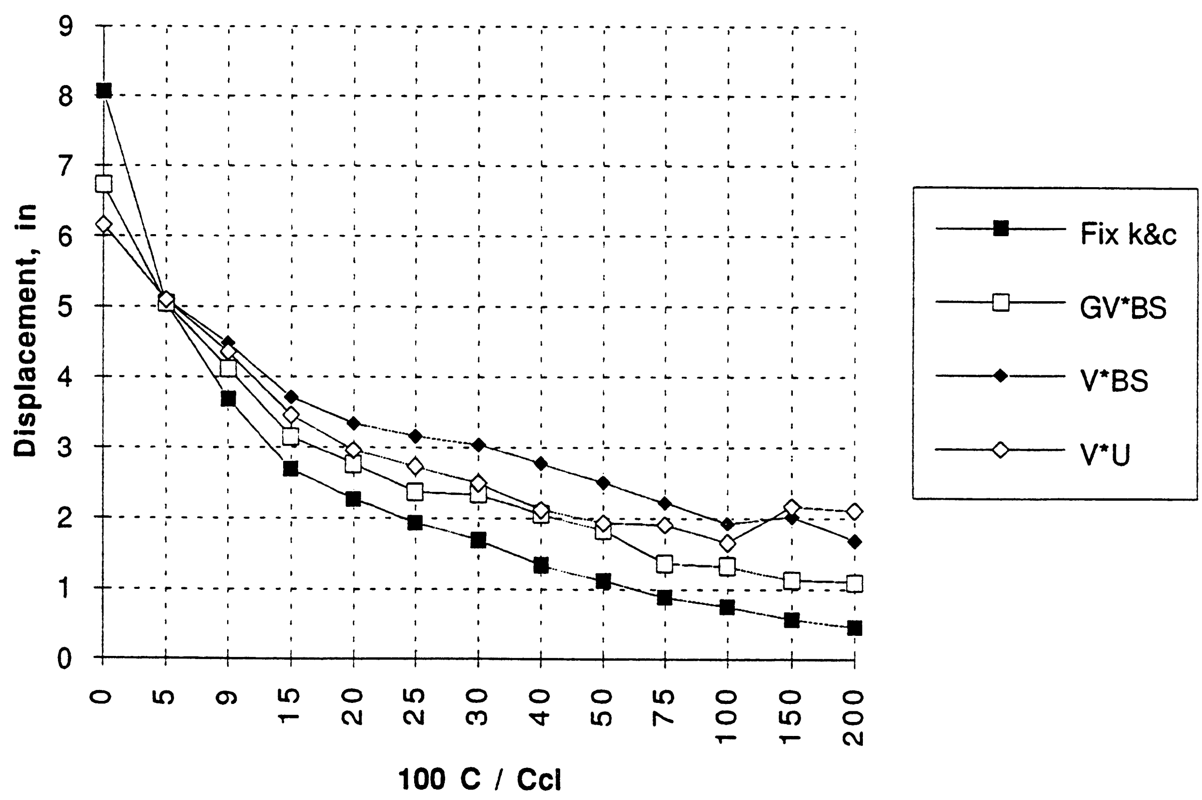
(The 30% point means the system has k=390 kip/in and c=30% critical. i.e. SDFS without control.)

The V*U(same) column: when V*U is negative c=c%(VARY); when positive c=5%(FIX).

(The 30% point means when V*U is neg. c=30%, k=390; when pos. c=5%, k=390.)

Displacement (Same stiffness 390) Fix stiff 5% (005.*)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	8.06	6.717	6.155	6.155
5	5.041	5.041	5.094	5.095
9	3.682	4.113	4.469	4.347
15	2.683	3.15	3.7	3.453
20	2.259	2.756	3.328	2.954
25	1.935	2.37	3.162	2.725
30	1.684	2.335	3.044	2.482
40	1.33	2.049	2.766	2.118
50	1.119	1.82	2.494	1.935
75	0.876	1.358	2.211	1.904
100	0.747	1.315	1.925	1.645
150	0.572	1.128	2.019	2.159
200	0.456	1.097	1.675	2.102



Description:

Here the stiffness always the same 390 kip/in.

Here provide Fix k&c for comparison, represent the case without controling.

(Different from the other columns, the damping ratio is always the same)

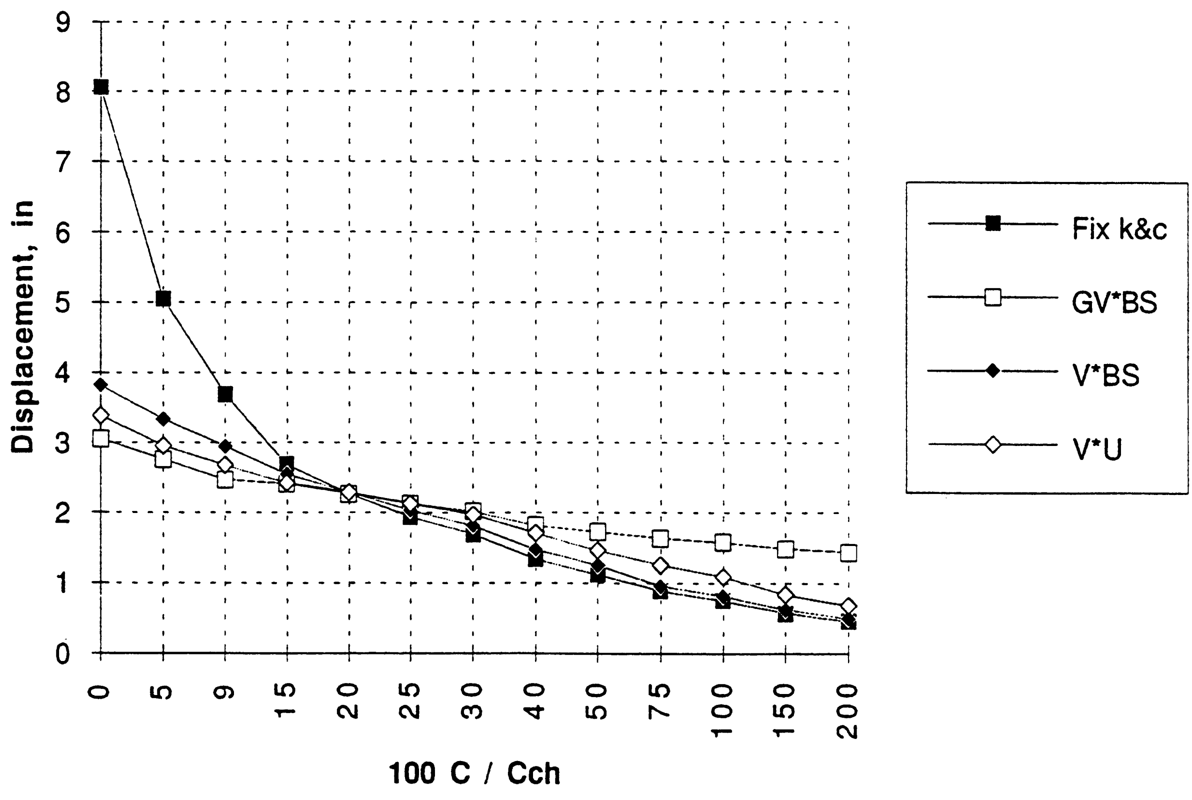
(The 30% point means the system has k=390 kip/in and c=30% critical. i.e. SDFS without control.)

The V*U(same) column: when V*U is negative c=20%(FIX); when positive c=c%(VARY).

(The 30% point means when V*U is neg. c=20%, k=390; when pos. c=30%, k=390.)

Displacement (Same stiffness 390) Fix soft 20% (*.020)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	8.06	3.046	3.807	3.382
5	5.041	2.756	3.328	2.954
9	3.682	2.465	2.941	2.672
15	2.683	2.406	2.542	2.413
20	2.259	2.259	2.282	2.283
25	1.935	2.127	2.03	2.126
30	1.684	2.01	1.808	1.97
40	1.33	1.807	1.463	1.694
50	1.119	1.719	1.252	1.457
75	0.876	1.63	0.951	1.251
100	0.747	1.575	0.814	1.088
150	0.572	1.487	0.617	0.8329
200	0.456	1.432	0.49	0.676



Description:

Here the stiffness always the same 390 kip/in.

Here provide Fix k&c for comparison, represent the case without controling.

(Different from the other columns, the damping ratio is always the same)

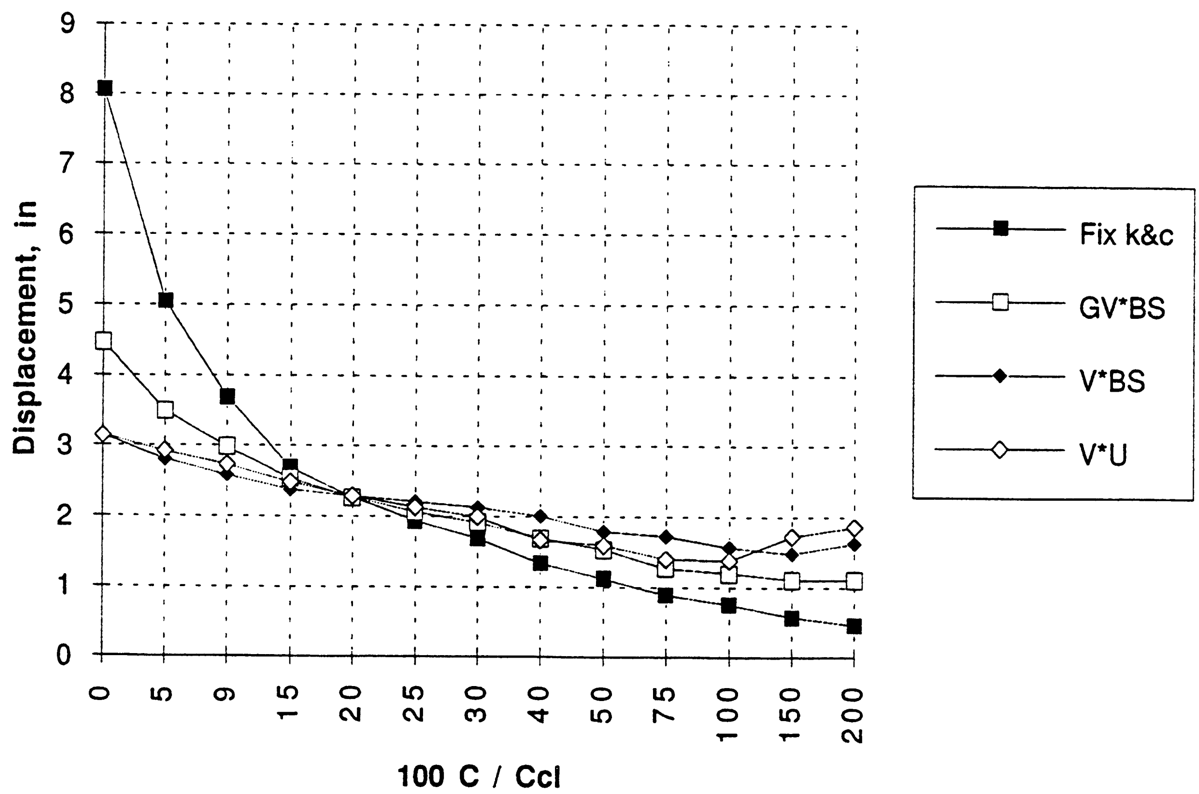
(The 30% point means the system has k=390 kip/in and c=30% critical. i.e. SDFS without control.)

The V*U(same) column: when V*U is negative c=c%(VARY); when positive c=20%(FIX).

(The 30% point means when V*U is neg. c=30%, k=390; when pos. c=20%, k=390.)

Displacement (Same stiffness 390) Fix stiff 20% (020.*)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	8.06	4.464	3.136	3.137
5	5.041	3.49	2.798	2.916
9	3.682	2.978	2.576	2.72
15	2.683	2.525	2.374	2.474
20	2.259	2.259	2.282	2.283
25	1.935	2.06	2.206	2.124
30	1.684	1.908	2.121	1.987
40	1.33	1.691	2	1.657
50	1.119	1.533	1.784	1.591
75	0.876	1.257	1.719	1.399
100	0.747	1.195	1.564	1.378
150	0.572	1.107	1.473	1.719
200	0.456	1.109	1.624	1.853



Description:

Here the stiffness always the same 390 kip/in.

Here provide Fix k&c for comparison, represent the case without controling.

(Different from the other columns, the damping ratio is always the same)

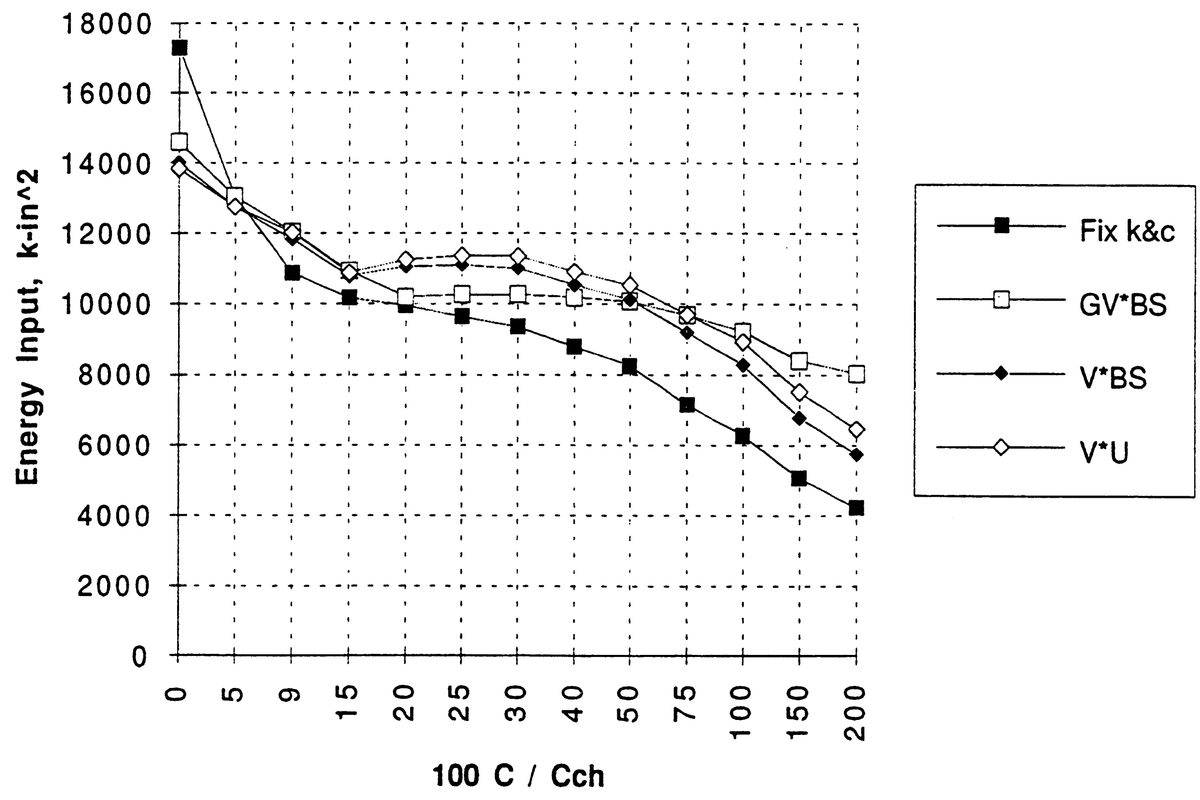
(The 30% point means the system has k=390 kip/in and c=30% critical. i.e. SDFS without control.)

The V*U(same) column: when V*U is negative c=5%(FIX); when positive c=c%(VARY).

(The 30% point means when V*U is neg. c=5%, k=390; when pos. c=30%, k=390.)

Energy Input (Same stiffness 390) Fix soft 5% (*.005)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	17288	14597	14005	13837
5	13023	13023	12733	12729
9	10868	12044	11821	12008
15	10150	10908	10767	10876
20	9937	10184	11039	11241
25	9634	10240	11085	11351
30	9326	10241	10987	11329
40	8759	10170	10520	10883
50	8237	10045	10102	10512
75	7138	9668	9171	9686
100	6277	9220	8268	8921
150	5042	8374	6775	7512
200	4210	8019	5735	6447



Description:

Here the stiffness always the same 390 kip/in.

Here provide Fix k&c for comparison, represent the case without controling.

(Different from the other columns, the damping ratio is always the same)

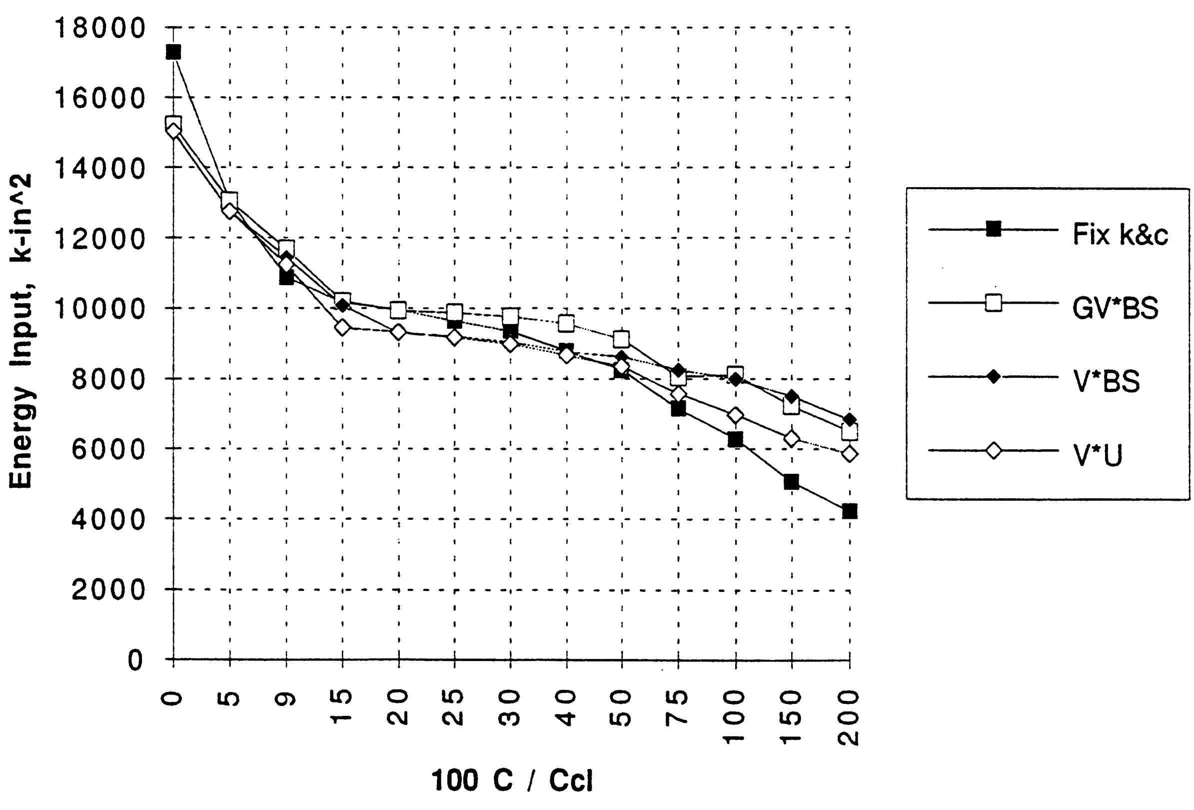
(The 30% point means the system has k=390 kip/in and c=30% critical. i.e. SDFS without control.)

The V*U(same) column: when V*U is negative c=c%(VARY); when positive c=5%(FIX).

(The 30% point means when V*U is neg. c=30%, k=390; when pos. c=5%, k=390.)

Energy Input (Same stiffness 390) Fix stiff 5% (005.*)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	17288	15226	15022	15028
5	13023	13023	12733	12729
9	10868	11675	11424	11214
15	10150	10184	10069	9436
20	9937	9925	9278	9307
25	9634	9857	9196	9165
30	9326	9745	9029	8973
40	8759	9556	8740	8648
50	8237	9125	8602	8333
75	7138	8037	8239	7563
100	6277	8094	7966	6949
150	5042	7205	7487	6289
200	4210	6487	6828	5847



Description:

Here the stiffness always the same 390 kip/in.

Here provide Fix k&c for comparison, represent the case without controling.

(Different from the other columns, the damping ratio is always the same)

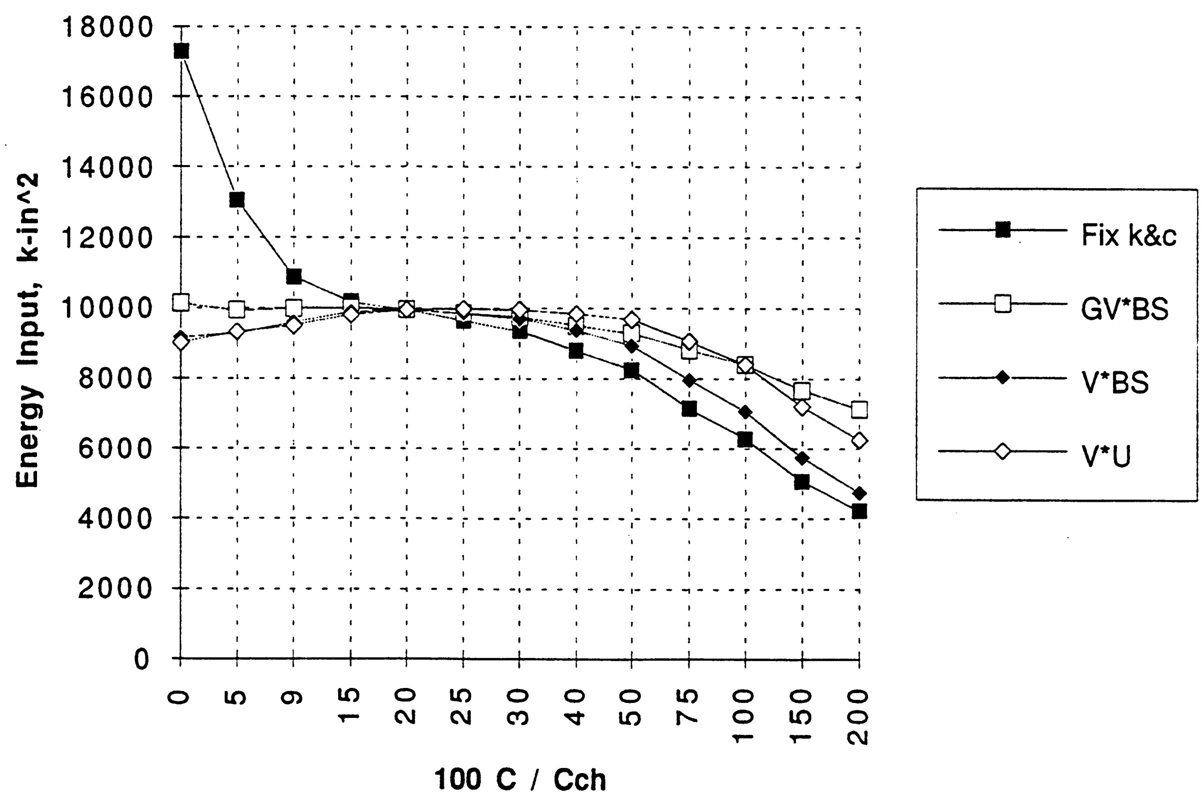
(The 30% point means the system has k=390 kip/in and c=30% critical. i.e. SDFS without control.)

The V*U(same) column: when V*U is negative c=20%(FIX); when positive c=c%(VARY).

(The 30% point means when V*U is neg. c=20%, k=390; when pos. c=30%, k=390.)

Energy Input (Same stiffness 390) Fix soft 20% (*.020)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	17288	10117	9129	8998
5	13023	9925	9278	9307
9	10868	9978	9568	9496
15	10150	9993	9868	9802
20	9937	9937	9938	9936
25	9634	9844	9839	9967
30	9326	9727	9684	9937
40	8759	9488	9357	9829
50	8237	9275	8933	9658
75	7138	8809	7959	9045
100	6277	8372	7060	8376
150	5042	7652	5741	7189
200	4210	7124	4747	6240



Description:

Here the stiffness always the same 390 kip/in.

Here provide Fix k&c for comparison, represent the case without controling.

(Different from the other columns, the damping ratio is always the same)

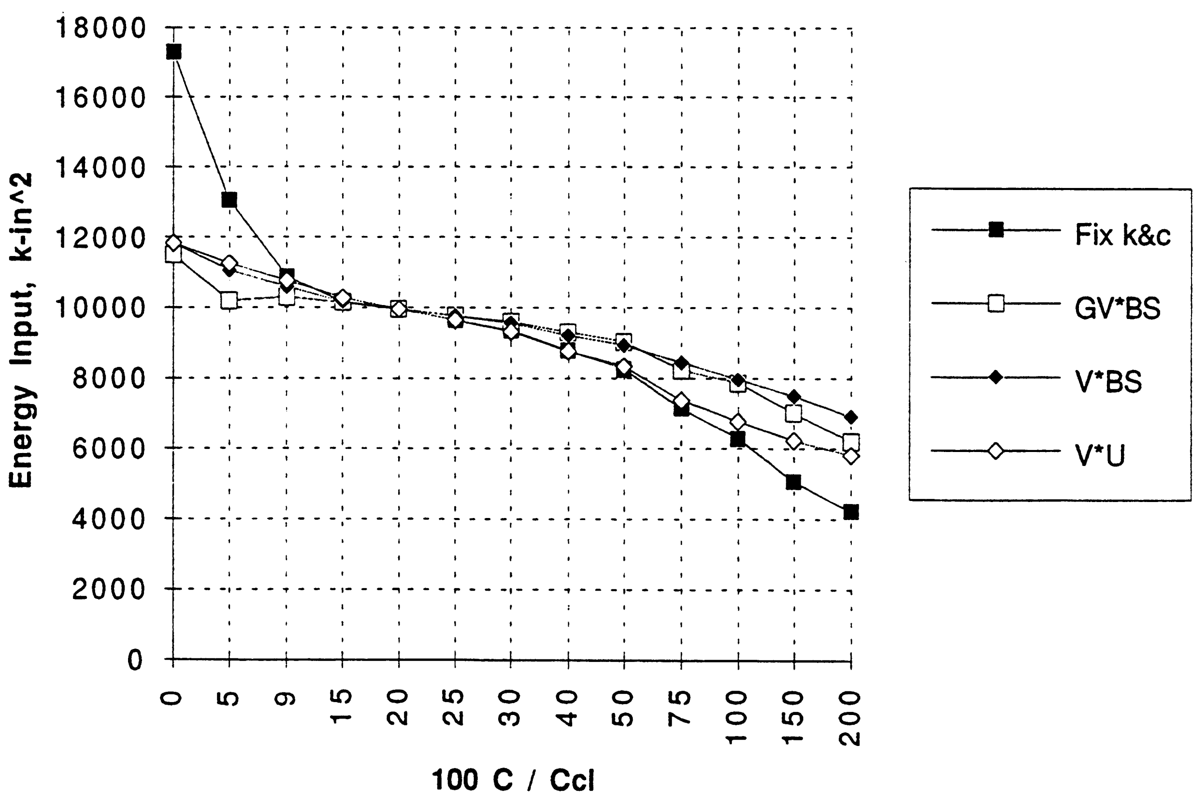
(The 30% point means the system has k=390 kip/in and c=30% critical. i.e. SDFS without control.)

The V*U(same) column: when V*U is negative c=c%(VARY); when positive c=20%(FIX).

(The 30% point means when V*U is neg. c=30%, k=390; when pos. c=20%, k=390.)

Energy Input (Same stiffness 390) Fix stiff 20% (020.*)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	17288	11476	11832	11832
5	13023	10184	11039	11241
9	10868	10283	10586	10752
15	10150	10131	10151	10261
20	9937	9937	9938	9936
25	9634	9748	9734	9621
30	9326	9576	9542	9316
40	8759	9289	9200	8747
50	8237	9011	8918	8314
75	7138	8231	8445	7363
100	6277	7862	7945	6753
150	5042	6990	7475	6226
200	4210	6198	6907	5808



Description:

Here the stiffness always the same 390 kip/in.

Here provide Fix k&c for comparison, represent the case without controling.

(Different from the other columns, the damping ratio is always the same)

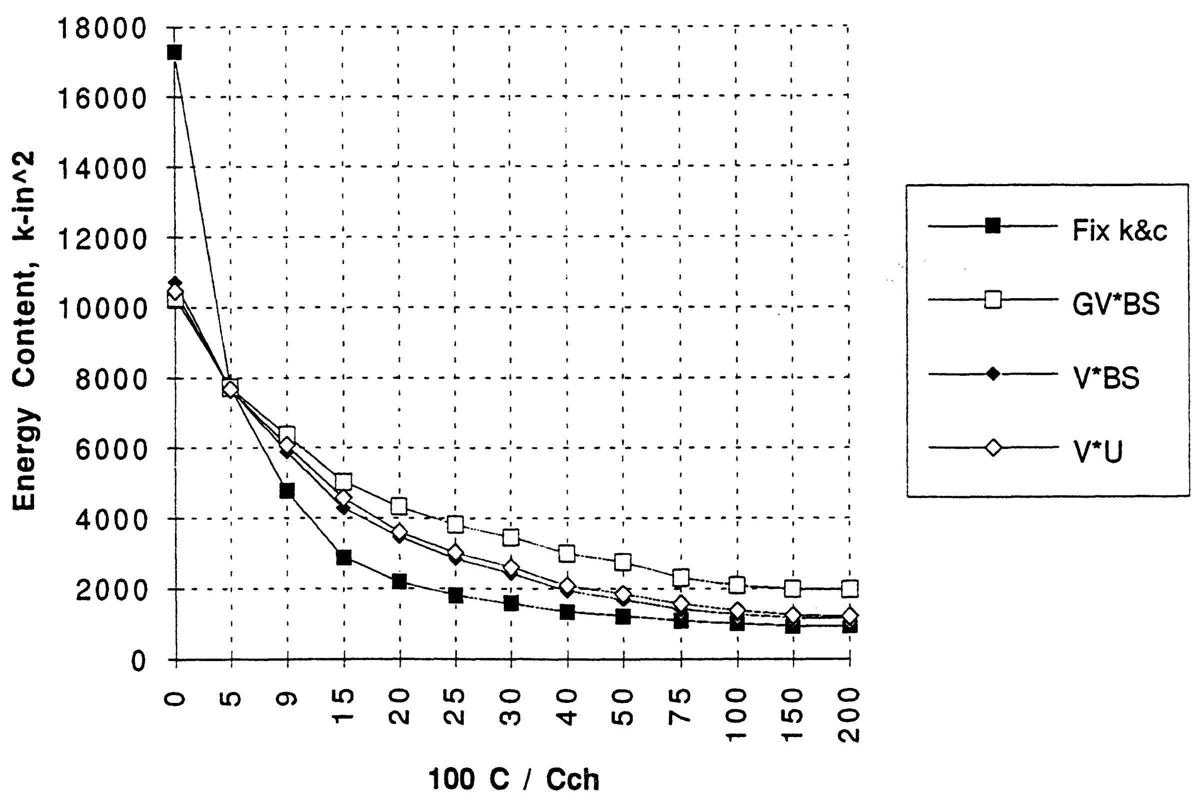
(The 30% point means the system has k=390 kip/in and c=30% critical. i.e. SDFS without control.)

The V*U(same) column: when V*U is negative c=5%(FIX); when positive c=c%(VARY).

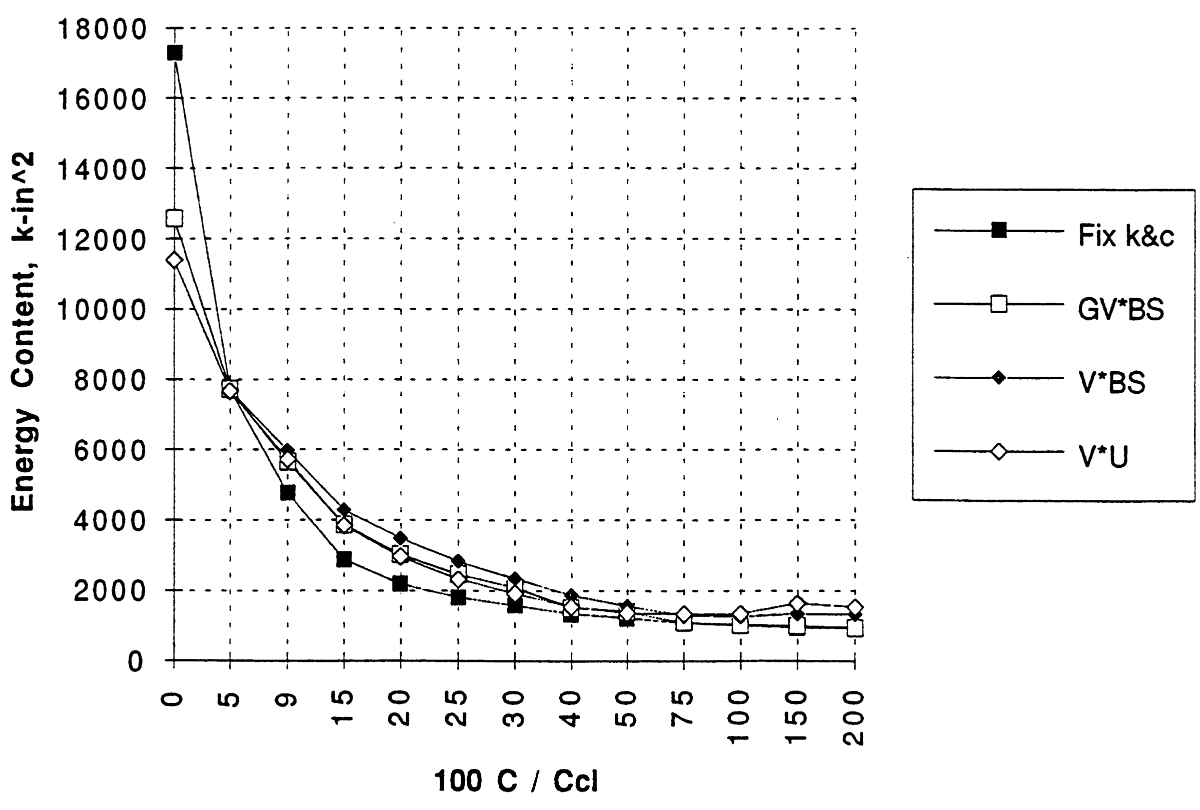
(The 30% point means when V*U is neg. c=5%, k=390; when pos. c=30%, k=390.)

KE + SE (Same stiffness 390) Fix soft 5% (*.005)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	17288	10273	10696	10439
5	7689	7689	7662	7661
9	4759	6358	5880	6057
15	2866	5035	4282	4565
20	2171	4311	3447	3593
25	1794	3805	2841	3005
30	1572	3444	2423	2605
40	1335	2984	1925	2068
50	1215	2731	1687	1848
75	1074	2302	1409	1568
100	1007	2070	1257	1365
150	935	1967	1153	1241
200	944	1961	1134	1192



Description:				
Here the stiffness always the same 390 kip/in.				
Here provide Fix k&c for comparison, represent the case without controling.				
(Different from the other columns, the damping ratio is always the same)				
(The 30% point means the system has k=390 kip/in and c=30% critical. i.e. SDFS without control.)				
The V*U(same) column: when V*U is negative c=c%(VARY); when positive c=5%(FIX).				
(The 30% point means when V*U is neg. c=30%, k=390; when pos. c=5%, k=390.)				
KE + SE (Same stiffness 390) Fix stiff 5% (005.*)				
c(%)	Fix k&c	GV*BS	V*BS	V*U
0	17288	12557	11368	11374
5	7689	7689	7662	7661
9	4759	5629	5969	5719
15	2866	3854	4262	3821
20	2171	2999	3471	2943
25	1794	2449	2816	2305
30	1572	2075	2324	1918
40	1335	1503	1865	1530
50	1215	1389	1553	1348
75	1074	1086	1293	1332
100	1007	1029	1257	1325
150	935	980	1330	1630
200	944	948	1341	1524



Description:

Here the stiffness always the same 390 kip/in.

Here provide Fix k&c for comparison, represent the case without controling.

(Different from the other columns, the damping ratio is always the same)

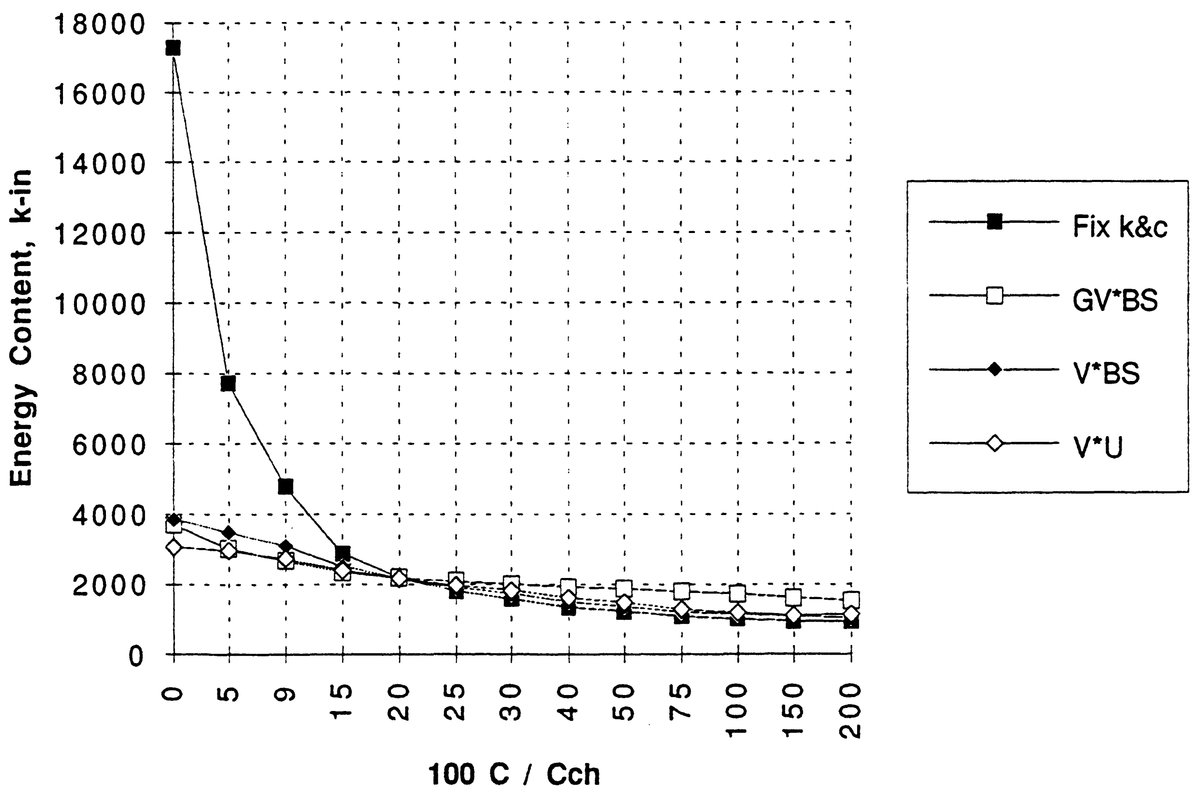
(The 30% point means the system has k=390 kip/in and c=30% critical. i.e. SDFS without control.)

The V*U(same) column: when V*U is negative c=20%(FIX); when positive c=c%(VARY).

(The 30% point means when V*U is neg. c=20%, k=390; when pos. c=30%, k=390.)

KE + SE (Same stiffness 390) Fix soft 20% (*.020)

c(%)	Fix k&c	GV*BS	V*BS	V*U
0	17288	3694	3835	3038
5	7689	2999	3471	2943
9	4759	2652	3092	2706
15	2866	2330	2496	2382
20	2171	2171	2152	2152
25	1794	2070	1889	1954
30	1572	2002	1715	1823
40	1335	1913	1490	1612
50	1215	1854	1354	1473
75	1074	1776	1190	1268
100	1007	1725	1133	1185
150	935	1608	1076	1099
200	944	1526	1033	1130



Description:

Here the stiffness always the same 390 kip/in.

Here provide Fix k&c for comparison, represent the case without controling.

(Different from the other columns, the damping ratio is always the same)

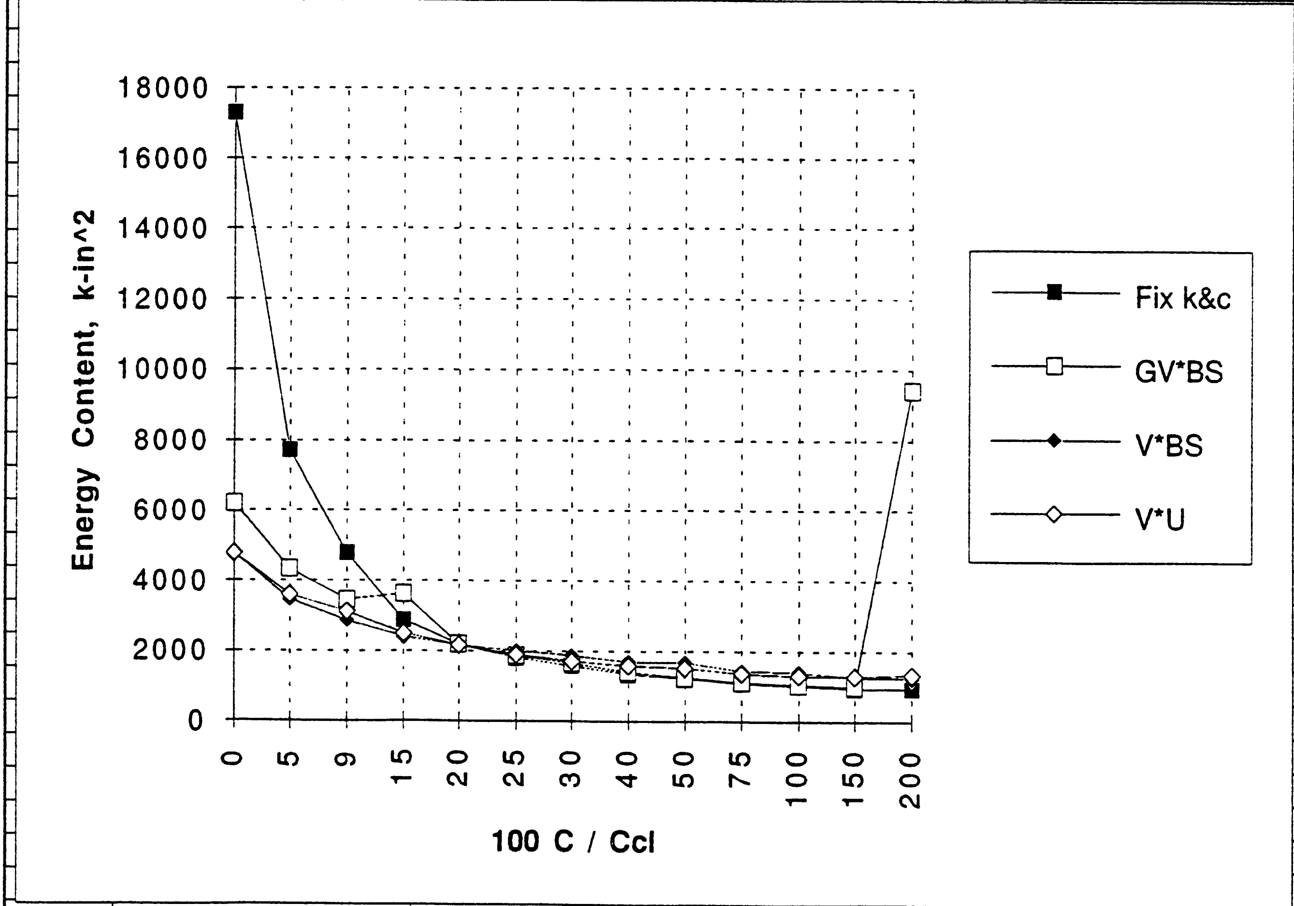
(The 30% point means the system has k=390 kip/in and c=30% critical. i.e. SDFS without control.)

The V*U(same) column: when V*U is negative c=c%(VARY); when positive c=20%(FIX).

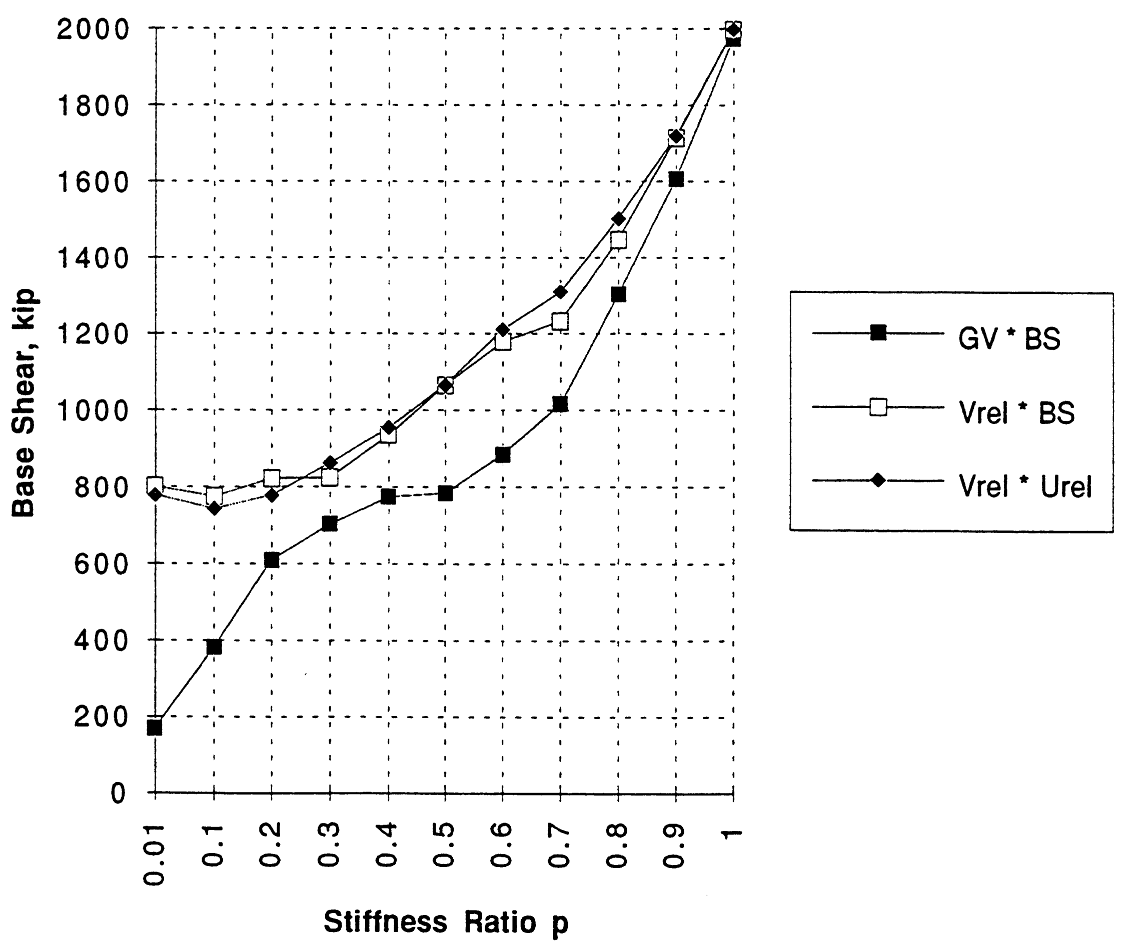
(The 30% point means when V*U is neg. c=30%, k=390; when pos. c=20%, k=390.)

KE + SE (Same stiffness 390) Fix stiff 20% (020.*)

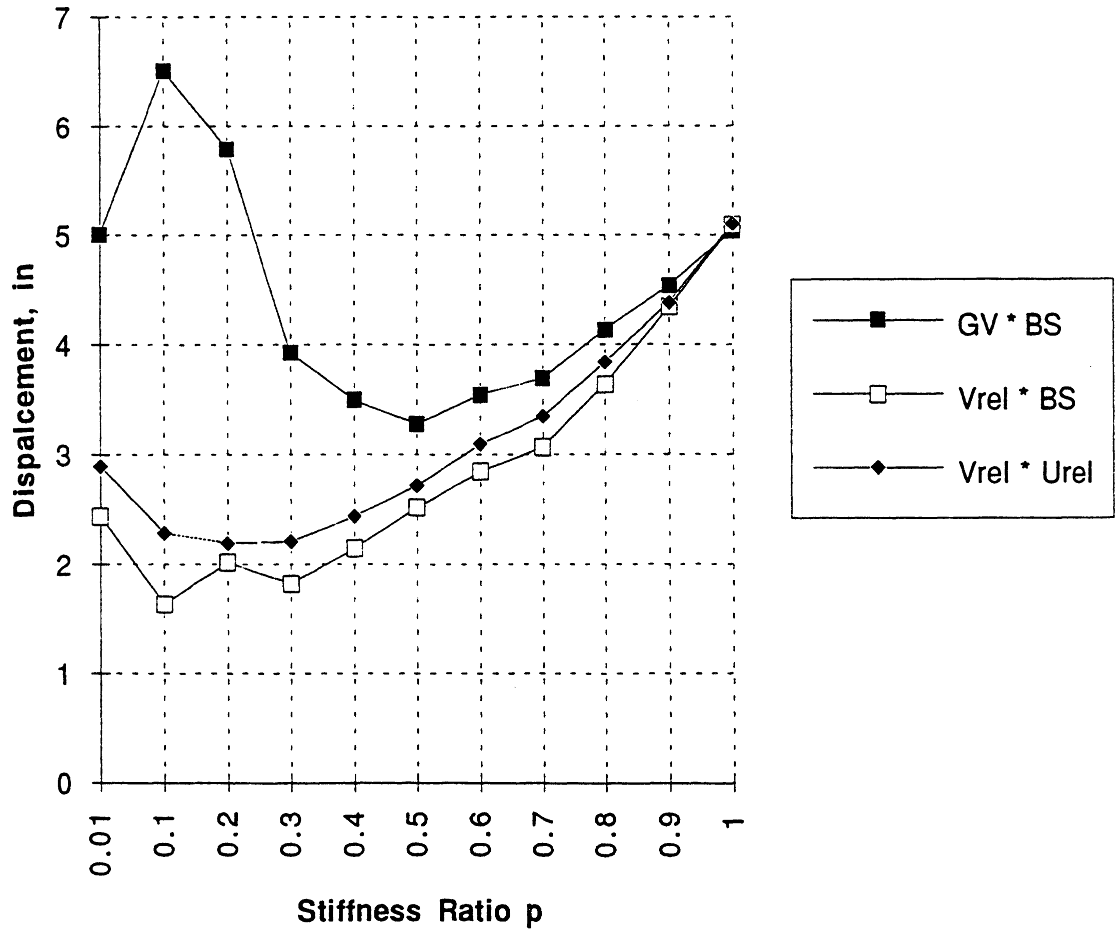
c(%)	Fix k&c	GV*BS	V*BS	V*U
0	17288	6204	4761	4761
5	7689	4311	3447	3593
9	4759	3452	2856	3112
15	2866	3620	2377	2489
20	2171	2171	2152	2152
25	1794	1861	1989	1872
30	1572	1645	1865	1693
40	1335	1383	1676	1576
50	1215	1241	1659	1497
75	1074	1093	1436	1349
100	1007	1038	1386	1289
150	935	984	1259	1279
200	944	9410	1239	1326



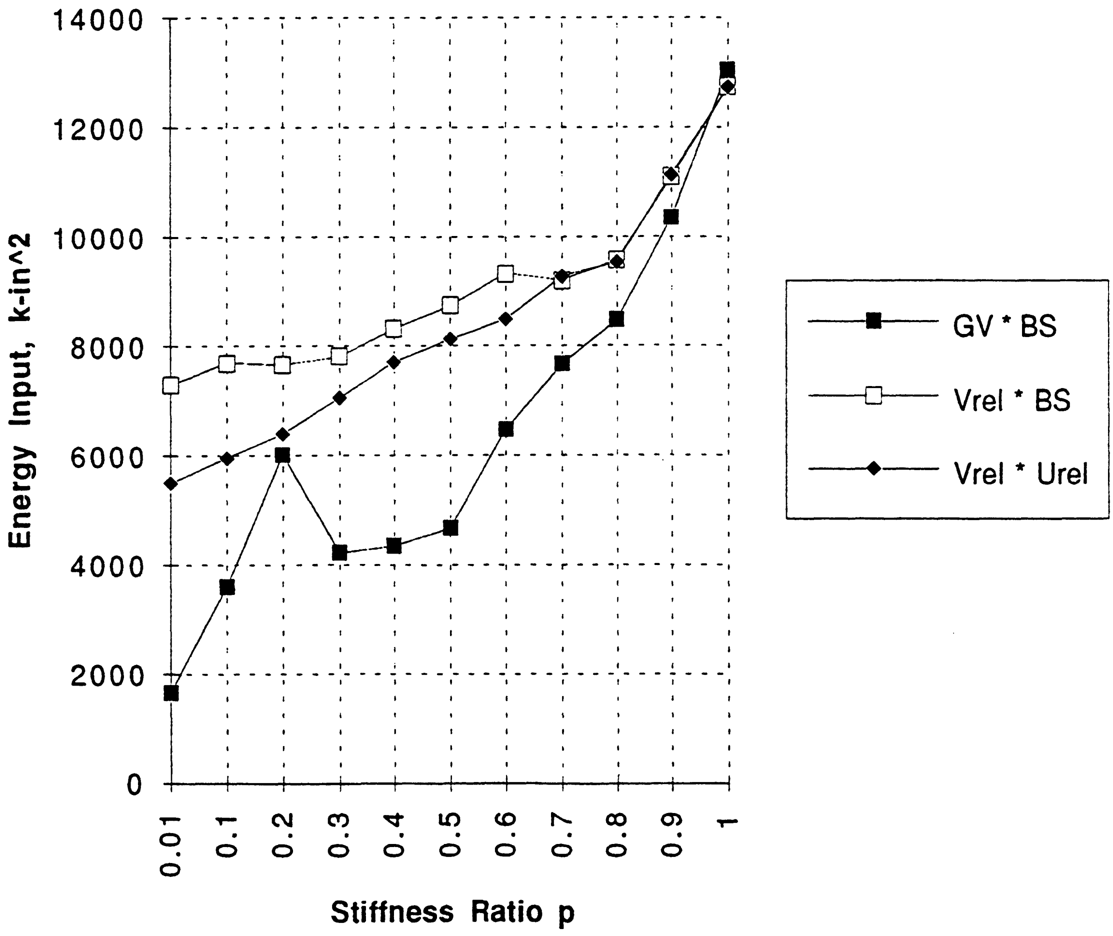
Description:				
Fix the system damping to 5% critical of 390 kip/in.				
When GV*BS, Vrel*BS, Vrel*Urel is negative, then change the system k to (pk*390);				
if positive then k=390. (pk=1 is the case without any control)				
Two ssstiffness: stiff 390k/in; soft (pk*390)				
Fix the damping 5% of stiff system (only change the stiffness)				
Base Shear				
stiff ratio (pk)	GV * BS	Vrel * BS	Vrel * Urel	soft damping ratio
0.01	169.2	800	777	50.00%
0.1	381	773	742	15.81%
0.2	608	822	776	11.18%
0.3	702	824	861	9.13%
0.4	773	935	953	7.91%
0.5	782	1064	1064	7.07%
0.6	884	1177	1209	6.45%
0.7	1015	1233	1310	5.98%
0.8	1302	1447	1502	5.59%
0.9	1606	1715	1718	5.27%
1	1976	1997	1997	5.00%



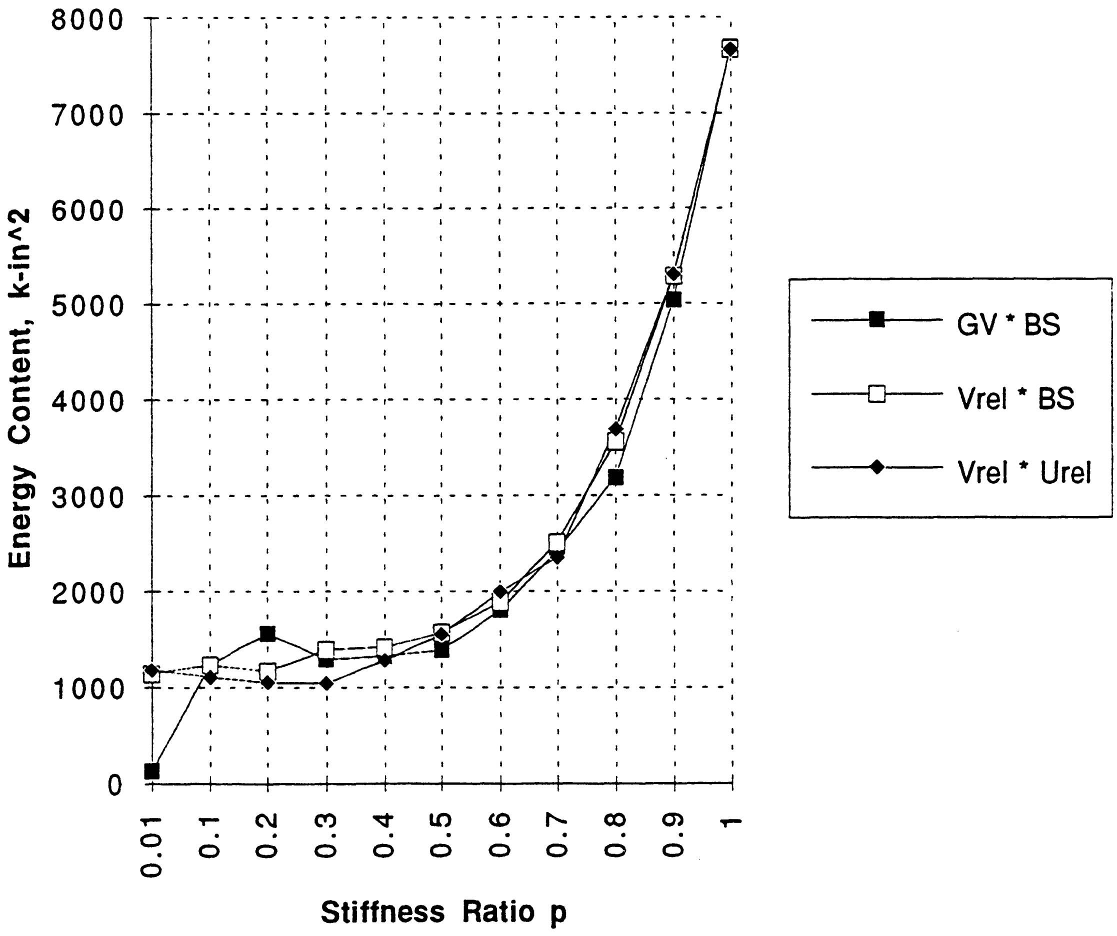
Description:				
Fix the system damping to 5% critical of 390 kip/in.				
When GV*BS, Vrel*BS, Vrel*Urel is negative, then change the system k to (pk*390);				
if positive then k=390. (pk=1 is the case without any control)				
Two ssstiffness: stiff 390k/in; soft (pk*390)				
Fix the damping 5% of stiff system (only change the stiffness)				
Displacement				
stiff ratio (pk)	GV * BS	Vrel * BS	Vrel * Urel	soft damping ratio
0.01	5.01	2.44	2.89	50.00%
0.1	6.51	1.63	2.28	15.81%
0.2	5.79	2.01	2.19	11.18%
0.3	3.92	1.82	2.2	9.13%
0.4	3.49	2.14	2.43	7.91%
0.5	3.27	2.51	2.71	7.07%
0.6	3.54	2.84	3.09	6.45%
0.7	3.69	3.06	3.34	5.98%
0.8	4.13	3.63	3.83	5.59%
0.9	4.54	4.34	4.38	5.27%
1	5.04	5.09	5.1	5.00%



Description:				
Fix the system damping to 5% critical of 390 kip/in.				
When GV*BS, Vrel*BS, Vrel*Urel is negative, then change the system k to (pk*390);				
if positive then k=390. (pk=1 is the case without any control)				
Two ssstiffness: stiff 390k/in; soft (pk*390)				
Fix the damping 5% of stiff system (only change the stiffness)				
Energy Input				
stiff ratio (pk)	GV * BS	Vrel * BS	Vrel * Urel	soft damping ratio
0.01	1650	7287	5486	50.00%
0.1	3586	7689	5955	15.81%
0.2	6010	7646	6389	11.18%
0.3	4209	7802	7047	9.13%
0.4	4334	8306	7700	7.91%
0.5	4666	8723	8110	7.07%
0.6	6457	9312	8479	6.45%
0.7	7668	9194	9269	5.98%
0.8	8463	9562	9524	5.59%
0.9	10337	11085	11133	5.27%
1	13023	12733	12729	5.00%



Description:				
Fix the system damping to 5% critical of 390 kip/in.				
When GV*BS, Vrel*BS, Vrel*Urel is negative, then change the system k to (pk*390);				
if positive then k=390. (pk=1 is the case without any control)				
Two ssstiffness: stiff 390k/in; soft (pk*390)				
Fix the damping 5% of stiff system (only change the stiffness)				
KE + SE				
stiff ratio (pk)	GV * BS	Vrel * BS	Vrel * Urel	soft damping ratio
0.01	128	1144	1177	50.00%
0.1	1233	1225	1104	15.81%
0.2	1558	1160	1046	11.18%
0.3	1293	1394	1040	9.13%
0.4	1324	1411	1276	7.91%
0.5	1384	1569	1551	7.07%
0.6	1802	1883	1992	6.45%
0.7	2418	2510	2351	5.98%
0.8	3183	3553	3688	5.59%
0.9	5035	5286	5303	5.27%
1	7688	7662	7661	5.00%



Description:

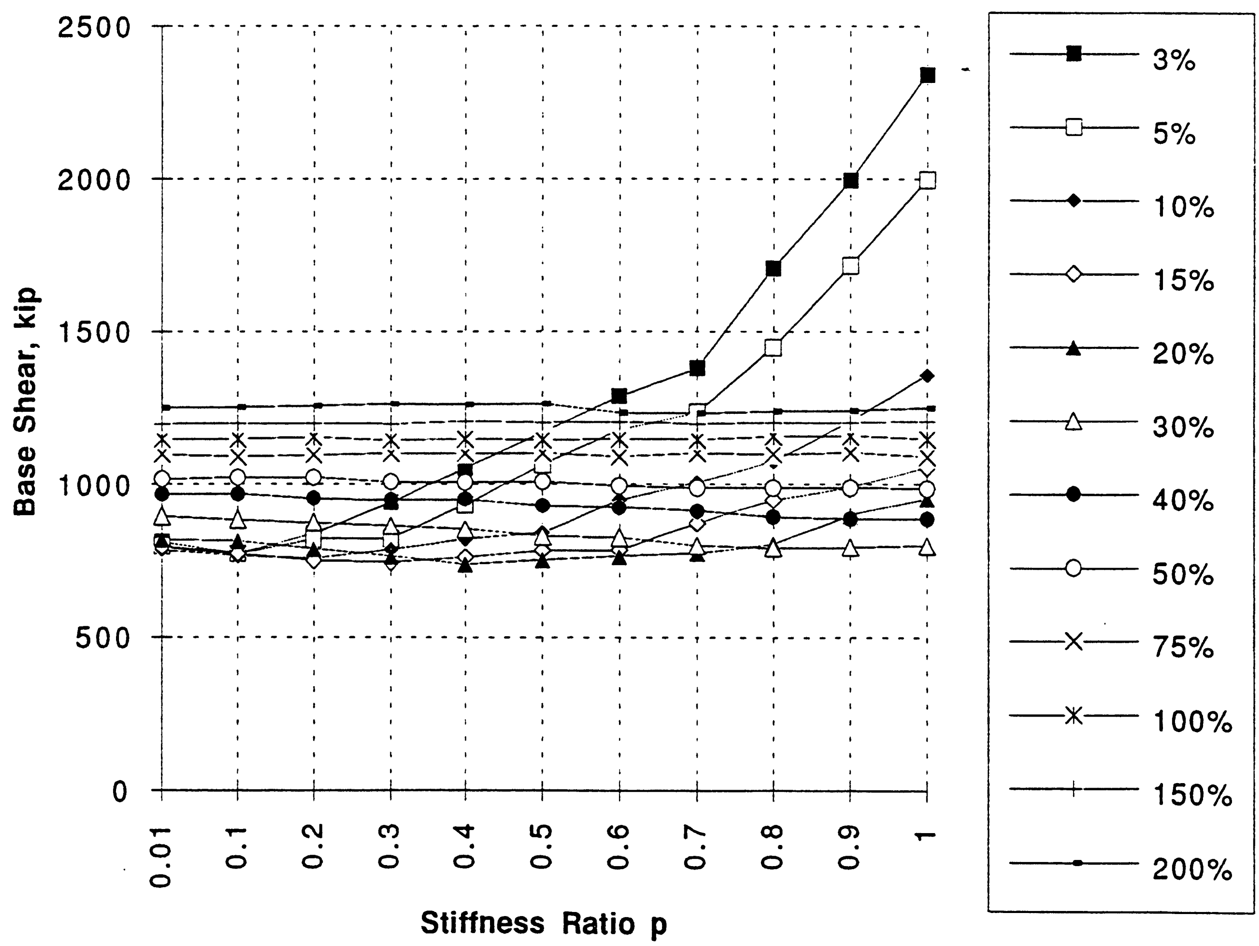
Here change the stiffness while damping stay the same. Each line represent one damping condition.
The c% column (eg. 3%, ...200%): means the damping of the system was FIXED to c% according to 390 kip/in. When Vrel*BS is pos. k=390; when neg. k=pk*390.(VARY)

Two ssstiffness: stiff 390k/in; soft (pk*390)

Fix the damping to different % of stiff system (only change the stiffness)

Base Shear

SR(pk)	3%	5%	10%	15%	20%	30%	40%	50%	75%	100%	150%	200%
0.01	814	800	787	795	821	897	969	1016	1097	1148	1197	1250
0.1	774	773	766	773	816	886	969	1023	1090	1149	1201	1252
0.2	841	822	757	751	792	877	954	1024	1096	1153	1200	1256
0.3	940	824	788	746	767	866	951	1007	1101	1144	1198	1263
0.4	1054	935	823	762	739	856	952	1006	1099	1148	1206	1260
0.5	1169	1064	843	784	753	831	929	1008	1102	1145	1203	1263
0.6	1288	1177	951	787	766	828	925	994	1090	1148	1204	1234
0.7	1379	1233	1006	873	775	802	913	988	1101	1147	1197	1232
0.8	1707	1447	1076	949	808	794	894	991	1097	1156	1202	1237
0.9	1994	1715	1204	990	900	796	889	989	1105	1157	1203	1240
1	2343	1997	1359	1056	954	803	887	985	1090	1148	1206	1249



Description:

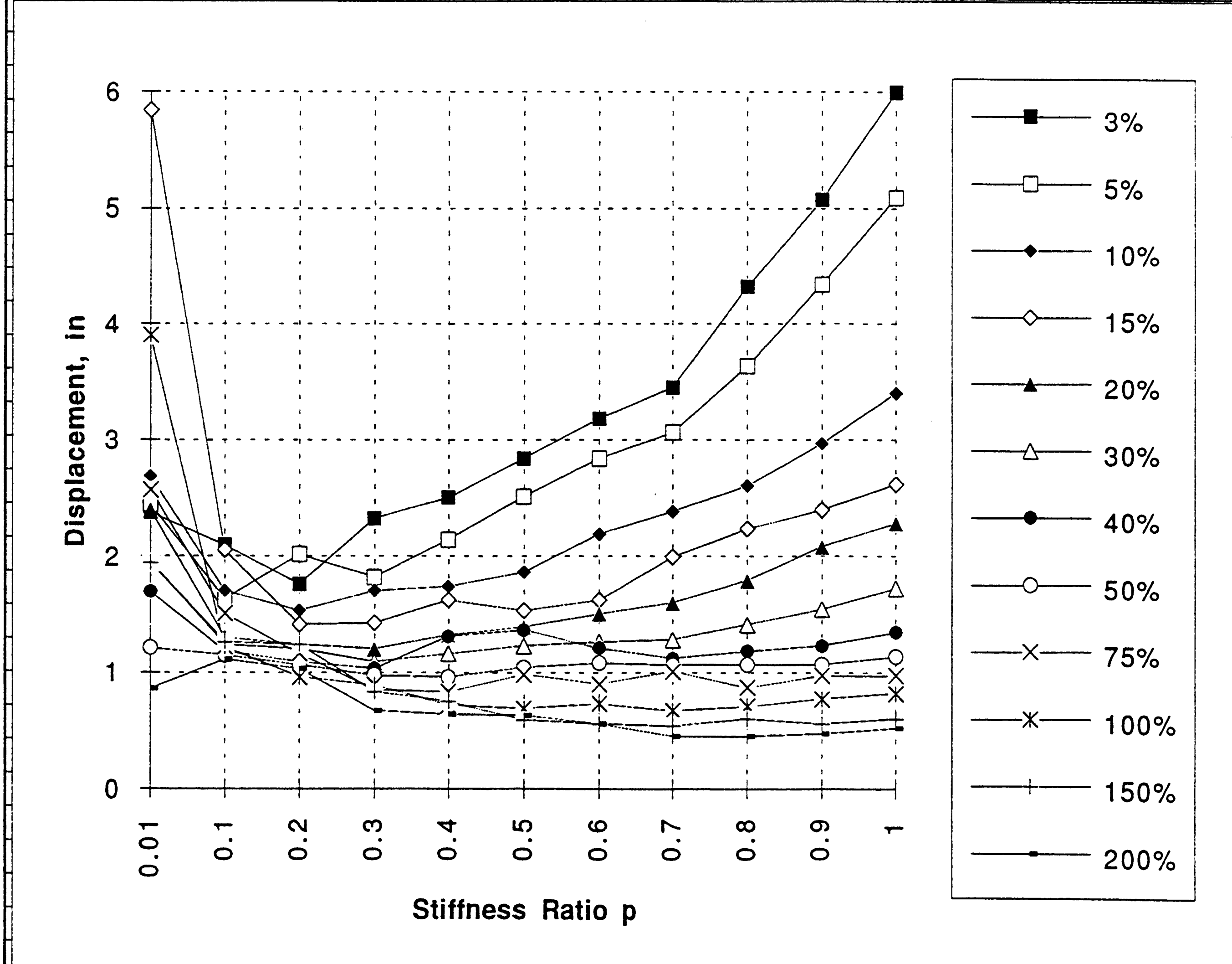
Here change the stiffness while damping stay the same. Each line represent one damping condition.
The c% column (eg. 3%, ...200%): means the damping of the system was FIXED to c% according to
390 kip/in. When Vrel*BS is pos. k=390; when neg. k=pk*390.(VARY)

Two ssstiffness: stiff 390k/in; soft (pk*390)

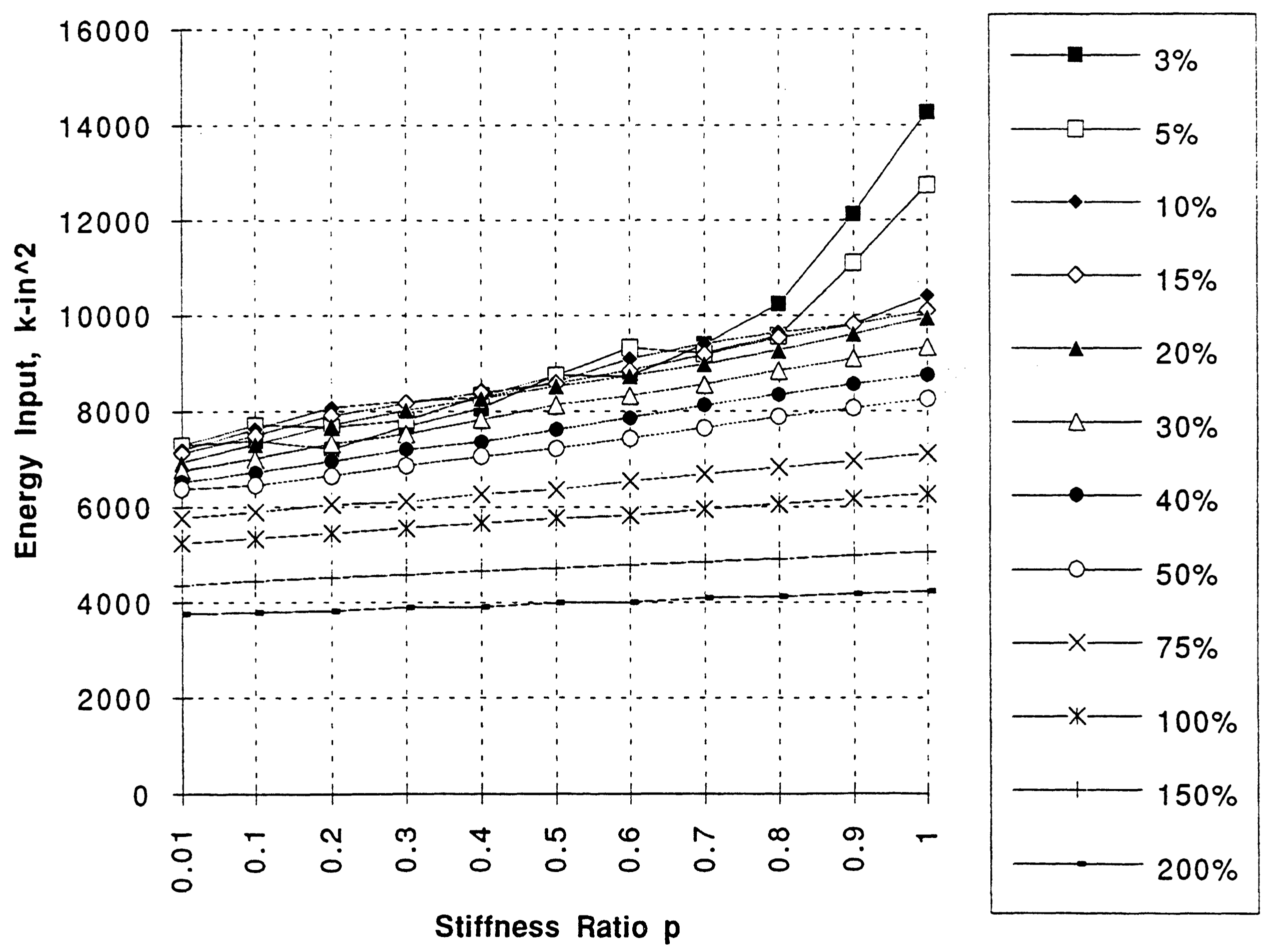
Fix the damping to different % of stiff system (only change the stiffness)

Displacemen

SR(pk)	3%	5%	10%	15%	20%	30%	40%	50%	75%	100%	150%	200%
0.01	2.37	2.44	2.68	5.84	2.39	1.95	1.69	1.21	2.57	3.9	1.94	0.86
0.1	2.09	1.63	1.7	2.05	1.3	1.24	1.18	1.15	1.5	1.22	1.26	1.11
0.2	1.76	2.01	1.53	1.41	1.24	1.2	1.09	1.06	1.16	0.96	1.24	1.03
0.3	2.32	1.82	1.7	1.42	1.2	1.09	1.03	0.97	0.85	0.89	0.83	0.67
0.4	2.5	2.14	1.74	1.62	1.32	1.16	1.31	0.96	0.83	0.72	0.75	0.64
0.5	2.84	2.51	1.86	1.53	1.39	1.23	1.36	1.04	0.98	0.69	0.59	0.63
0.6	3.18	2.84	2.19	1.62	1.5	1.26	1.21	1.08	0.9	0.73	0.56	0.56
0.7	3.45	3.06	2.38	1.99	1.6	1.28	1.12	1.06	1.01	0.67	0.54	0.45
0.8	4.32	3.63	2.6	2.23	1.79	1.41	1.18	1.07	0.87	0.71	0.6	0.45
0.9	5.07	4.34	2.96	2.39	2.08	1.54	1.23	1.07	0.97	0.77	0.56	0.47
1	5.99	5.09	3.4	2.62	2.28	1.72	1.34	1.13	0.97	0.82	0.6	0.52



Description:												
Here change the stiffness while damping stay the same. Each line represent one damping condition.												
The c% column (eg. 3%, ...200%): means the damping of the system was FIXED to c% according to												
390 kip/in. When Vrel*BS is pos. k=390; when neg. k=pk*390.(VARY)												
Two ssstiffness: stiff 390k/in; soft (pk*390)												
Fix the damping to different % of stiff system (only change the stiffness)												
Energy Input												
SR(pk)	3%	5%	10%	15%	20%	30%	40%	50%	75%	100%	150%	200%
0.01	7275	7287	7184	7115	6925	6749	6505	6362	5759	5239	4368	3757
0.1	7366	7689	7611	7476	7293	6995	6713	6433	5881	5328	4443	3790
0.2	7187	7646	8064	7900	7695	7311	6945	6644	6036	5435	4522	3825
0.3	7663	7802	8195	8152	8006	7507	7183	6856	6099	5543	4577	3888
0.4	8056	8306	8281	8377	8250	7817	7357	7033	6266	5651	4669	3898
0.5	8737	8723	8595	8574	8512	8120	7597	7216	6355	5750	4714	3985
0.6	8708	9312	9078	8832	8722	8317	7848	7417	6524	5807	4788	4001
0.7	9387	9194	9402	9168	8964	8548	8105	7633	6662	5934	4843	4085
0.8	10223	9562	9641	9534	9270	8842	8335	7873	6817	6051	4907	4122
0.9	12123	11085	9799	9795	9604	9080	8548	8053	6939	6156	4977	4172
1	14276	12733	10403	10087	9938	9330	8734	8237	7100	6258	5047	4228



Description:

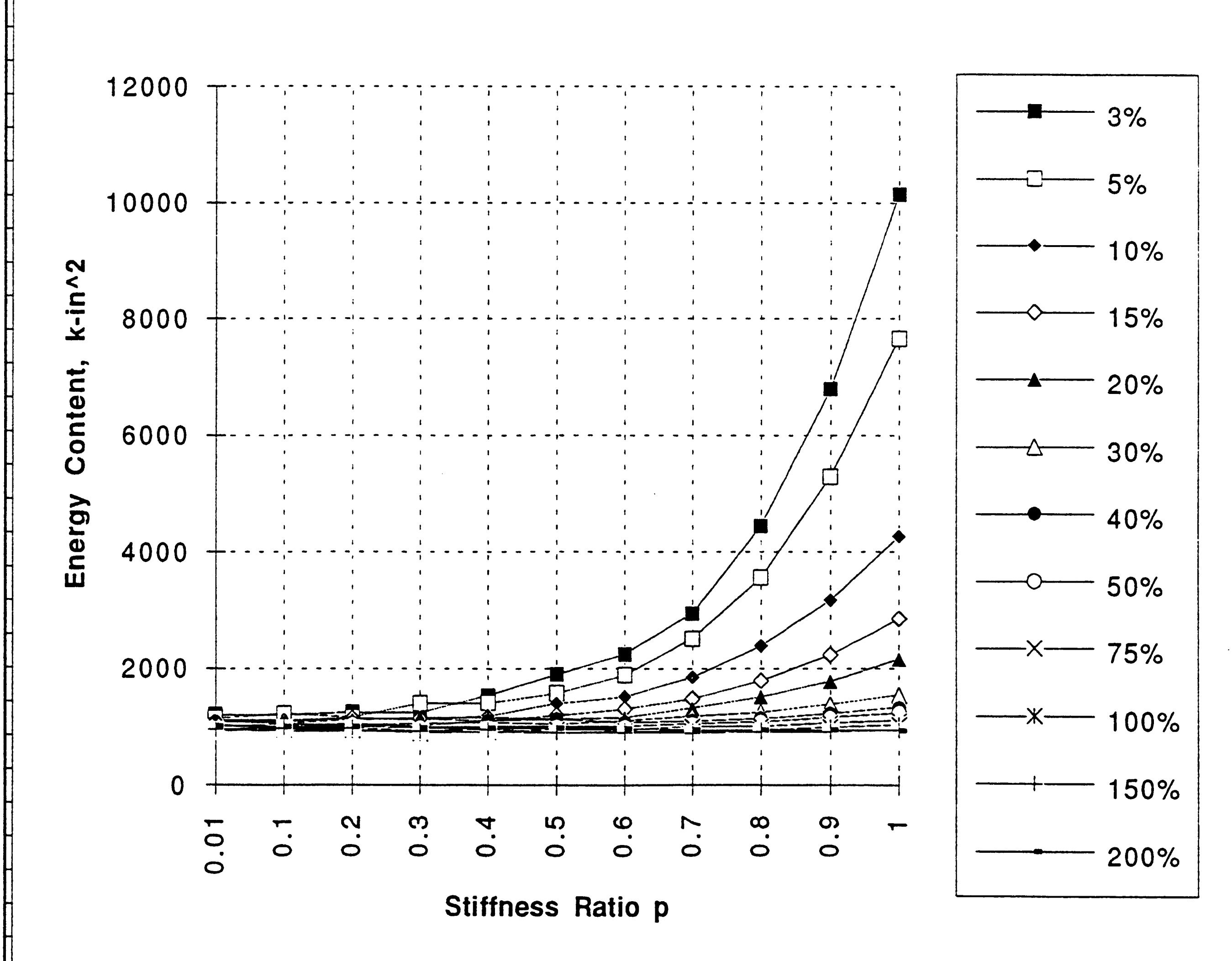
Here change the stiffness while damping stay the same. Each line represent one damping condition.
The c% column (eg. 3%, ...200%): means the damping of the system was FIXED to c% according to
390 kip/in. When Vrel*BS is pos. k=390; when neg. k=pk*390.(VARY)

Two ssstiffness: stiff 390k/in; soft (pk*390)

Fix the damping to different % of stiff system (only change the stiffness)

KE + SE

SR(pk)	3%	5%	10%	15%	20%	30%	40%	50%	75%	100%	150%	200%
0.01	1205	1144	1120	1079	1092	1027	1001	943	943	929	959	1010
0.1	1204	1225	1107	1080	1054	992	1040	1011	921	953	978	997
0.2	1248	1160	1145	1144	1112	1016	1018	1047	912	944	973	996
0.3	1240	1394	1113	1140	1148	1052	1010	985	928	892	921	975
0.4	1532	1411	1176	1097	1163	1072	1103	994	904	915	956	975
0.5	1884	1569	1398	1187	1125	1040	1125	1007	960	893	902	976
0.6	2243	1883	1510	1294	1160	1110	1070	1013	943	921	901	964
0.7	2941	2510	1842	1482	1319	1183	1098	1050	1006	917	887	946
0.8	4443	3553	2380	1784	1511	1242	1138	1086	1005	949	910	940
0.9	6783	5286	3163	2227	1766	1383	1226	1156	1066	985	918	944
1	10140	7662	4260	2848	2152	1549	1334	1238	1105	1027	942	938



Program Flow-chart and Listing

Program Flow-chart

Every program is developed according to the following flow-chart:

Read input data from data file

Calculate system response through Subroutine Response

Subroutine Response includes the follows:

Calculate miscellaneous constants(damping ratio,period etc.), initial conditions

Select appropriate integrate step, and calculate the exciting forces

Use Subroutine Solve to calculate the displacement, velocity, acceleration, etc. using the exciting forces

Use Subroutine Base to calculate the base shear using the results from Sub Solve

Overshooting the time whenever the control parameter changes sign, then recalculate base shear, velocity, acceleration, displacement,etc.

Use Subroutine State to perform semi-active control according to the algorithms

Do the necessary adjustments(base shear,etc.) due to state change

Use Subroutine Energy to calculate the energy level

Procede to output, including peak values and other detailed data

Repeat the calculation for the next integral interval

Program Listing

An input sample data and three sets of programs used to perform the simulation are provided for reference. These three programs include the semi-active damping control bi-linear system (I-A), semi-active stiffness system (I-B), and semi-active stiffness control for different damping (II-B) using (*V*BS*) as control parameter.

ACTIVE DAMPER SYSTEM

10.0	390.0	1.5	0.05	0.05	0.001	1.0	
1000	0.00	386.0 (8F10.3)					
0.020	-0.001	0.040	-0.011	0.060	-0.010	0.080	-0.009
0.100	-0.010	0.120	-0.012	0.140	-0.014	0.160	-0.013
0.180	-0.011	0.200	-0.009	0.220	-0.009	0.240	-0.013
0.260	-0.018	0.280	-0.020	0.300	-0.016	0.320	-0.015
0.340	-0.011	0.360	-0.008	0.380	-0.004	0.400	-0.007
0.420	-0.013	0.440	-0.019	0.460	-0.020	0.480	-0.007
0.500	0.003	0.520	0.014	0.540	-0.005	0.560	-0.013
0.580	-0.015	0.600	-0.021	0.620	-0.026	0.640	-0.033
0.660	-0.031	0.680	-0.017	0.700	-0.020	0.720	-0.017
0.740	-0.017	0.760	-0.007	0.780	0.003	0.800	0.015
0.820	0.024	0.840	0.026	0.860	0.034	0.880	0.047
0.900	0.050	0.920	0.042	0.940	0.036	0.960	0.027
0.980	0.024	1.000	0.034	1.020	0.042	1.040	0.054
1.060	0.065	1.080	0.074	1.100	0.066	1.120	0.061
1.140	0.041	1.160	0.041	1.180	0.006	1.200	-0.052
1.220	-0.080	1.240	-0.061	1.260	-0.049	1.280	-0.025
1.300	-0.006	1.320	0.014	1.340	0.031	1.360	0.051
1.380	0.072	1.400	0.101	1.420	0.124	1.440	0.155
1.460	0.147	1.480	0.117	1.500	0.095	1.520	0.090
1.540	0.094	1.560	0.085	1.580	0.091	1.600	0.101
1.620	0.123	1.640	0.033	1.660	-0.150	1.680	-0.210
1.700	-0.202	1.720	-0.206	1.740	-0.184	1.760	-0.175
1.780	-0.178	1.800	-0.178	1.820	-0.183	1.840	-0.165
1.860	-0.137	1.880	-0.110	1.900	-0.079	1.920	-0.044
1.940	-0.002	1.960	0.037	1.980	0.080	2.000	0.118
2.020	0.162	2.040	0.199	2.060	0.245	2.080	0.277
2.100	0.308	2.120	0.325	2.140	0.347	2.160	0.286
2.180	0.236	2.200	-0.122	2.220	-0.241	2.240	-0.166
2.260	-0.189	2.280	-0.111	2.300	-0.076	2.320	-0.018
2.340	0.011	2.360	0.054	2.380	0.091	2.400	0.120
2.420	0.178	2.440	0.058	2.460	-0.267	2.480	-0.157
2.500	-0.175	2.520	-0.103	2.540	-0.059	2.560	0.024
2.580	-0.068	2.600	-0.201	2.620	-0.166	2.640	-0.171
2.660	-0.150	2.680	-0.125	2.700	-0.102	2.720	-0.076
2.740	-0.053	2.760	-0.027	2.780	-0.004	2.800	0.019
2.820	-0.010	2.840	-0.044	2.860	-0.085	2.880	-0.096
2.900	-0.073	2.920	-0.061	2.940	-0.034	2.960	-0.011
2.980	0.019	3.000	0.043	3.020	0.068	3.040	-0.010
3.060	-0.038	3.080	-0.004	3.100	0.001	3.120	0.035
3.140	0.057	3.160	0.090	3.180	0.115	3.200	0.138
3.220	0.022	3.240	0.024	3.260	0.069	3.280	0.070
3.300	0.134	3.320	0.137	3.340	0.207	3.360	-0.094
3.380	-0.133	3.400	-0.070	3.420	-0.055	3.440	0.007
3.460	0.068	3.480	-0.108	3.500	-0.151	3.520	-0.109
3.540	-0.118	3.560	-0.077	3.580	-0.057	3.600	-0.022
3.620	-0.013	3.640	-0.068	3.660	-0.033	3.680	-0.034
3.700	-0.011	3.720	0.002	3.740	0.030	3.760	0.049
3.780	0.062	3.800	0.023	3.820	-0.003	3.840	-0.025
3.860	0.008	3.880	0.021	3.900	0.058	3.920	0.084
3.940	0.122	3.960	0.150	3.980	0.176	4.000	0.043
4.020	0.003	4.040	0.026	4.060	0.030	4.080	-0.006
4.100	-0.015	4.120	0.015	4.140	0.021	4.160	0.051
4.180	0.065	4.200	0.097	4.220	0.114	4.240	0.147
4.260	0.165	4.280	0.197	4.300	0.188	4.320	0.201
4.340	0.179	4.360	0.127	4.380	-0.122	4.400	-0.055
4.420	-0.039	4.440	-0.032	4.460	-0.113	4.480	-0.168
4.500	-0.250	4.520	-0.205	4.540	-0.186	4.560	-0.134
4.580	-0.097	4.600	-0.033	4.620	0.016	4.640	0.083
4.660	0.134	4.680	0.184	4.700	-0.006	4.720	-0.017
4.740	0.029	4.760	0.045	4.780	0.100	4.800	0.144
4.820	0.188	4.840	0.249	4.860	0.171	4.880	-0.140
4.900	-0.101	4.920	-0.110	4.940	-0.092	4.960	-0.048
4.980	-0.127	5.000	-0.214	5.020	-0.164	5.040	-0.172

5.060	-0.132	5.080	-0.113	5.100	-0.078	5.120	-0.052
5.140	-0.055	5.160	-0.122	5.180	-0.123	5.200	-0.117
5.220	-0.116	5.240	-0.073	5.260	-0.055	5.280	0.006
5.300	-0.082	5.320	-0.166	5.340	-0.087	5.360	-0.097
5.380	-0.040	5.400	-0.015	5.420	0.032	5.440	0.066
5.460	0.089	5.480	0.048	5.500	0.020	5.520	-0.003
5.540	0.030	5.560	0.045	5.580	0.080	5.600	0.105
5.620	0.137	5.640	0.163	5.660	0.189	5.680	0.130
5.700	0.065	5.720	0.021	5.740	0.032	5.760	0.038
5.780	0.050	5.800	0.024	5.820	-0.009	5.840	-0.017
5.860	-0.011	5.880	-0.023	5.900	-0.025	5.920	-0.016
5.940	-0.007	5.960	0.015	5.980	0.038	6.000	0.059
6.020	0.026	6.040	-0.004	6.060	-0.043	6.080	-0.013
6.100	0.010	6.120	0.023	6.140	-0.013	6.160	-0.005
6.180	0.008	6.200	0.021	6.220	0.039	6.240	0.052
6.260	0.016	6.280	-0.003	6.300	-0.011	6.320	0.001
6.340	0.008	6.360	0.004	6.380	-0.010	6.400	-0.004
6.420	-0.002	6.440	0.004	6.460	0.009	6.480	-0.006
6.500	-0.031	6.520	-0.043	6.540	-0.025	6.560	-0.024
6.580	-0.018	6.600	-0.013	6.620	-0.002	6.640	0.021
6.660	-0.011	6.680	-0.009	6.700	-0.003	6.720	-0.011
6.740	-0.011	6.760	-0.010	6.780	0.000	6.800	0.007
6.820	0.024	6.840	0.036	6.860	0.072	6.880	0.079
6.900	0.019	6.920	-0.027	6.940	-0.013	6.960	-0.004
6.980	0.016	7.000	0.005	7.020	-0.022	7.040	-0.047
7.060	-0.043	7.080	-0.022	7.100	-0.004	7.120	0.016
7.140	0.032	7.160	0.042	7.180	0.012	7.200	-0.016
7.220	-0.021	7.240	-0.008	7.260	-0.021	7.280	-0.014
7.300	-0.006	7.320	0.005	7.340	0.014	7.360	0.027
7.380	0.024	7.400	0.008	7.420	-0.001	7.440	0.020
7.460	0.044	7.480	0.050	7.500	0.019	7.520	0.009
7.540	-0.002	7.560	-0.002	7.580	0.005	7.600	0.009
7.620	0.026	7.640	0.037	7.660	0.053	7.680	0.055
7.700	0.043	7.720	0.040	7.740	0.057	7.760	0.077
7.780	0.037	7.800	0.042	7.820	0.010	7.840	-0.021
7.860	-0.025	7.880	-0.041	7.900	-0.042	7.920	-0.048
7.940	-0.044	7.960	-0.046	7.980	-0.006	8.000	0.018
8.020	-0.021	8.040	-0.050	8.060	-0.054	8.080	-0.037
8.100	-0.041	8.120	-0.031	8.140	-0.032	8.160	-0.027
8.180	-0.027	8.200	-0.027	8.220	-0.035	8.240	-0.031
8.260	-0.022	8.280	-0.008	8.300	0.009	8.320	0.028
8.340	0.031	8.360	0.036	8.380	0.035	8.400	0.036
8.420	0.029	8.440	0.031	8.460	0.011	8.480	0.022
8.500	0.014	8.520	0.039	8.540	-0.087	8.560	-0.137
8.580	-0.136	8.600	-0.137	8.620	-0.121	8.640	-0.106
8.660	-0.084	8.680	-0.066	8.700	-0.045	8.720	-0.026
8.740	-0.006	8.760	-0.009	8.780	-0.018	8.800	-0.015
8.820	0.009	8.840	0.017	8.860	0.005	8.880	0.027
8.900	0.059	8.920	0.088	8.940	0.122	8.960	0.172
8.980	0.113	9.000	-0.112	9.020	-0.037	9.040	-0.045
9.060	-0.024	9.080	-0.097	9.100	-0.067	9.120	-0.061
9.140	-0.068	9.160	-0.056	9.180	-0.003	9.200	0.038
9.220	0.109	9.240	0.169	9.260	0.096	9.280	0.041
9.300	0.068	9.320	0.013	9.340	-0.010	9.360	-0.053
9.380	-0.084	9.400	-0.117	9.420	-0.117	9.440	-0.081
9.460	-0.037	9.480	0.003	9.500	0.055	9.520	0.119
9.540	0.163	9.560	-0.027	9.580	0.003	9.600	-0.006
9.620	0.002	9.640	0.015	9.660	0.054	9.680	0.081
9.700	-0.021	9.720	-0.060	9.740	-0.017	9.760	-0.018
9.780	-0.003	9.800	0.008	9.820	0.039	9.840	0.058
9.860	0.076	9.880	0.081	9.900	0.060	9.920	0.031
9.940	0.002	9.960	0.006	9.980	-0.041	10.000	-0.046
10.020	-0.008	10.040	0.017	10.060	0.058	10.080	0.009
10.100	-0.006	10.120	0.004	10.140	-0.012	10.160	-0.029
10.180	-0.044	10.200	-0.036	10.220	-0.026	10.240	-0.011
10.260	0.021	10.280	0.053	10.300	0.087	10.320	0.116

10.340	0.074	10.360	0.024	10.380	-0.037	10.400	-0.027
10.420	-0.022	10.440	-0.089	10.460	-0.099	10.480	-0.060
10.500	-0.034	10.520	0.008	10.540	0.026	10.560	0.052
10.580	0.037	10.600	0.008	10.620	-0.006	10.640	-0.021
10.660	-0.032	10.680	-0.024	10.700	-0.038	10.720	-0.056
10.740	-0.073	10.760	-0.081	10.780	-0.053	10.800	-0.034
10.820	-0.001	10.840	0.007	10.860	-0.004	10.880	-0.001
10.900	-0.017	10.920	-0.042	10.940	-0.008	10.960	0.008
10.980	0.038	11.000	0.062	11.020	0.067	11.040	0.026
11.060	-0.006	11.080	-0.048	11.100	-0.036	11.120	-0.025
11.140	-0.005	11.160	0.013	11.180	0.038	11.200	0.024
11.220	-0.023	11.240	-0.043	11.260	-0.069	11.280	-0.067
11.300	-0.060	11.320	-0.052	11.340	-0.041	11.360	-0.031
11.380	-0.027	11.400	-0.055	11.420	-0.064	11.440	-0.092
11.460	-0.112	11.480	-0.089	11.500	-0.078	11.520	-0.059
11.540	-0.048	11.560	-0.034	11.580	-0.020	11.600	0.002
11.620	0.021	11.640	0.044	11.660	0.062	11.680	0.078
11.700	0.095	11.720	0.108	11.740	0.115	11.760	0.120
11.780	0.126	11.800	0.135	11.820	0.162	11.840	0.182
11.860	0.207	11.880	0.125	11.900	0.045	11.920	-0.014
11.940	-0.068	11.960	-0.056	11.980	-0.070	12.000	-0.100
12.020	-0.126	12.040	-0.120	12.060	-0.106	12.080	-0.093
12.100	-0.075	12.120	-0.082	12.140	-0.086	12.160	-0.087
12.180	-0.088	12.200	-0.089	12.220	-0.088	12.240	-0.090
12.260	-0.054	12.280	0.005	12.300	0.022	12.320	0.025
12.340	0.059	12.360	0.032	12.380	0.024	12.400	0.049
12.420	0.060	12.440	0.053	12.460	0.036	12.480	0.020
12.500	0.020	12.520	0.050	12.540	0.035	12.560	0.029
12.580	0.044	12.600	0.024	12.620	0.009	12.640	0.008
12.660	-0.015	12.680	-0.008	12.700	-0.002	12.720	0.008
12.740	0.004	12.760	-0.015	12.780	-0.032	12.800	-0.024
12.820	-0.003	12.840	0.018	12.860	0.043	12.880	0.045
12.900	0.052	12.920	0.047	12.940	0.049	12.960	0.020
12.980	0.023	13.000	0.028	13.020	0.040	13.040	0.051
13.060	0.059	13.080	0.060	13.100	0.083	13.120	0.081
13.140	0.096	13.160	0.035	13.180	0.005	13.200	-0.012
13.220	-0.035	13.240	-0.043	13.260	-0.042	13.280	-0.028
13.300	-0.027	13.320	0.008	13.340	0.043	13.360	-0.023
13.380	-0.039	13.400	-0.008	13.420	0.014	13.440	0.045
13.460	0.003	13.480	-0.071	13.500	-0.081	13.520	-0.025
13.540	-0.014	13.560	0.008	13.580	-0.012	13.600	-0.025
13.620	-0.034	13.640	-0.027	13.660	-0.031	13.680	-0.020
13.700	-0.007	13.720	-0.004	13.740	0.011	13.760	0.030
13.780	0.035	13.800	0.097	13.820	0.091	13.840	0.018
13.860	-0.037	13.880	-0.101	13.900	-0.082	13.920	-0.075
13.940	-0.055	13.960	-0.033	13.980	-0.013	14.000	0.003
14.020	0.015	14.040	0.052	14.060	-0.002	14.080	-0.050
14.100	-0.036	14.120	-0.070	14.140	-0.052	14.160	-0.038
14.180	0.009	14.200	0.064	14.220	0.085	14.240	0.129
14.260	0.141	14.280	0.121	14.300	0.076	14.320	0.023
14.340	-0.009	14.360	-0.023	14.380	0.008	14.400	0.018
14.420	0.055	14.440	0.040	14.460	0.005	14.480	-0.008
14.500	-0.019	14.520	-0.002	14.540	0.001	14.560	-0.012
14.580	-0.021	14.600	-0.031	14.620	-0.052	14.640	-0.074
14.660	-0.059	14.680	-0.027	14.700	-0.018	14.720	0.004
14.740	0.010	14.760	0.014	14.780	0.022	14.800	0.044
14.820	0.009	14.840	-0.056	14.860	-0.056	14.880	-0.025
14.900	-0.008	14.920	0.025	14.940	0.042	14.960	0.018
14.980	-0.003	15.000	-0.025	15.020	-0.002	15.040	0.025
15.060	0.049	15.080	0.079	15.100	0.063	15.120	0.034
15.140	-0.001	15.160	-0.020	15.180	-0.025	15.200	-0.022
15.220	-0.011	15.240	0.005	15.260	0.024	15.280	-0.003
15.300	-0.022	15.320	-0.048	15.340	-0.037	15.360	-0.020
15.380	-0.002	15.400	0.017	15.420	-0.008	15.440	0.001
15.460	0.023	15.480	0.038	15.500	0.061	15.520	0.052
15.540	0.044	15.560	0.035	15.580	0.051	15.600	0.066

15.620	0.069	15.640	0.017	15.660	-0.017	15.680	-0.053
15.700	-0.067	15.720	-0.039	15.740	-0.023	15.760	-0.003
15.780	0.012	15.800	-0.013	15.820	-0.036	15.840	-0.052
15.860	-0.034	15.880	-0.022	15.900	-0.001	15.920	0.014
15.940	0.007	15.960	-0.006	15.980	-0.012	16.000	-0.033
16.020	-0.035	16.040	-0.009	16.060	0.007	16.080	0.031
16.100	0.048	16.120	0.061	16.140	0.058	16.160	0.033
16.180	-0.007	16.200	-0.079	16.220	-0.062	16.240	-0.044
16.260	-0.021	16.280	0.003	16.300	0.035	16.320	0.030
16.340	0.012	16.360	0.034	16.380	0.032	16.400	0.026
16.420	0.021	16.440	0.020	16.460	0.018	16.480	0.002
16.500	-0.015	16.520	-0.035	16.540	-0.034	16.560	-0.015
16.580	-0.003	16.600	0.017	16.620	-0.010	16.640	-0.026
16.660	-0.028	16.680	-0.039	16.700	-0.025	16.720	-0.022
16.740	-0.018	16.760	-0.018	16.780	-0.004	16.800	-0.003
16.820	-0.019	16.840	-0.012	16.860	0.009	16.880	0.035
16.900	0.070	16.920	0.092	16.940	0.087	16.960	0.077
16.980	0.052	17.000	0.019	17.020	0.002	17.040	-0.019
17.060	-0.015	17.080	-0.007	17.100	0.002	17.120	0.013
17.140	0.022	17.160	0.002	17.180	-0.013	17.200	-0.033
17.220	-0.053	17.240	-0.072	17.260	-0.059	17.280	-0.047
17.300	-0.031	17.320	-0.015	17.340	-0.001	17.360	-0.018
17.380	-0.032	17.400	-0.047	17.420	-0.040	17.440	-0.035
17.460	-0.032	17.480	-0.044	17.500	-0.050	17.520	-0.048
17.540	-0.043	17.560	-0.037	17.580	-0.028	17.600	-0.026
17.620	-0.014	17.640	-0.007	17.660	0.051	17.680	0.073
17.700	0.089	17.720	0.079	17.740	0.078	17.760	0.045
17.780	0.008	17.800	0.001	17.820	-0.013	17.840	-0.002
17.860	0.003	17.880	0.011	17.900	0.011	17.920	0.020
17.940	0.021	17.960	0.008	17.980	-0.006	18.000	-0.007
18.020	0.007	18.040	0.011	18.060	0.015	18.080	-0.001
18.100	-0.016	18.120	-0.019	18.140	-0.001	18.160	0.016
18.180	0.011	18.200	-0.012	18.220	-0.031	18.240	-0.031
18.260	-0.010	18.280	-0.006	18.300	0.000	18.320	0.002
18.340	0.005	18.360	0.006	18.380	0.010	18.400	0.014
18.420	0.018	18.440	0.022	18.460	0.026	18.480	0.031
18.500	0.035	18.520	0.039	18.540	0.048	18.560	0.040
18.580	0.024	18.600	0.012	18.620	-0.008	18.640	-0.013
18.660	0.005	18.680	0.003	18.700	-0.025	18.720	-0.057
18.740	-0.064	18.760	-0.060	18.780	-0.042	18.800	-0.007
18.820	0.028	18.840	0.028	18.860	-0.002	18.880	-0.006
18.900	-0.011	18.920	-0.022	18.940	-0.042	18.960	-0.053
18.980	-0.023	19.000	0.003	19.020	0.008	19.040	0.014
19.060	0.017	19.080	0.026	19.100	0.033	19.120	0.040
19.140	0.017	19.160	-0.014	19.180	-0.033	19.200	-0.030
19.220	-0.029	19.240	-0.031	19.260	-0.034	19.280	-0.025
19.300	-0.008	19.320	0.013	19.340	0.038	19.360	0.041
19.380	0.025	19.400	0.016	19.420	-0.004	19.440	-0.016
19.460	-0.029	19.480	-0.032	19.500	-0.011	19.520	0.010
19.540	0.034	19.560	0.058	19.580	0.043	19.600	0.015
19.620	-0.001	19.640	-0.014	19.660	-0.027	19.680	-0.035
19.700	-0.036	19.720	-0.040	19.740	-0.041	19.760	-0.049
19.780	-0.049	19.800	-0.041	19.820	-0.041	19.840	-0.036
19.860	-0.019	19.880	-0.006	19.900	0.004	19.920	-0.002
19.940	-0.007	19.960	-0.017	19.980	-0.012	20.000	0.013

```
C       PROGRAM FOR CASE I-A
C       ***  Use Vrel* BSrel for controlling
C       ***  Bilinear stiffness
C
C*************************************************************

      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      CHARACTER*20 FMT
      CHARACTER*10 HED
C
C     DYNAMIC ANALYSIS OF SINGLE DEGREE OF FREEDOM SYSTEMS
C     WITH THE FOLLOWING FORCE-DEFORMATION MECHANICAL CHARACTERISTICS
C      SIGN BASE-SHEAR .EQ. SIGN GROUND VELOCITY : MIN.STIFFNESS
C      SIGN BASE-SHEAR .NE. SIGN GROUND VELOCITY : MAX.STIFFNESS
C
C     PROGRAMMED BY JODI FIRMANSJAH, CORRECTED AND EXTENDED BY I-HONG CHEN
C
C     SOME KEY VARIABLES
C       XMASS      =  MASS
C       STIFF      =  MAXIMUM STIFFNESS
C       PK         =  RATIO OF MINIMUM STIFFNESS TO MAXIMUM STIFFNESS
C       DAMP1      =  DAMPING RATIO OF MAXIMUN STIFFNESS SYSTEM
C       DAMP2      =  DAMPING RATIO OF MINIMUM STIFFNESS SYSTEM
C       DELTAT     =  INTEGRATION INTERVAL
C       XOUT       =  OUTPUT INTERVAL
C
C       KOUNT      =  NO. GROUND ACCELERATION RECORD
C       FACTOR     =  MAGNIFICATION FACTOR
C       FY         =  YIEDING FORCE OF BILINEAR SYS FOR BOTH T & C
C
      COMMON /BLK5/ DF,FC,FT,FY,FYC1,FYT1,UC,UT,KEY,KEY0
      COMMON /BLK1/ XMASS,STIFF,PSTIFF,ST,FACTOR,C1,C2,HED
      COMMON /BLK2/ DAMP1,DOUT,PK,DAMP2,KOUNT
      COMMON /BLK3/ DELTAT,P1,P2,DP,U1,U2,F1,F2,T1,T2,V1,V2,A1,A2
      COMMON /BLK8/ RU,F1C,F2C
      COMMON /ACCL/ TT(2000),PP(2000)
      COMMON /RESP/ UU(100000),VV(100000),AA(100000),RR(100000),
     1              TO(100000),CC(100000)
      COMMON /BLK9/ BSMAX,BSMIN,DISMAX,DISMIN,EDMAX,EIMAX,
     1              EKSMAX,EKTMAX
      COMMON /TIME/ TBSMAX,TBSMIN,TDIMAX,TDIMIN,TEDMAX,TEIMAX,
     1              TESMAX,TETMAX

      CHARACTER*24 INP
C
C     OPEN EXTERNAL FILES
C
      WRITE(*,5)
5     FORMAT(' input file')
      READ(*,10) INP
10    FORMAT(a24)

C
      OPEN(5,FILE=INP)
      OPEN(6,FILE='out200.020')
      OPEN(1,FILE='file1200.020')
      OPEN(7,FILE='file7200.020')
      OPEN(10,FILE='state200.020')
      OPEN(11,FILE='dis200.020')
      OPEN(12,FILE='bs200.020')
      OPEN(13,FILE='gv200.020')
      OPEN(UNIT=14,FILE='sg200.020')
      OPEN(2,FILE='eks200.020')
      OPEN(18,FILE='ekt200.020')
      OPEN(17,FILE='ed200.020')
      OPEN(21,FILE='stiff200.020')
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```
      OPEN(UNIT=15,FILE='ei200.020')
      OPEN(20,FILE='max200.020')
C
C     READ HEADING AND SYSTEM INFORMATION
C
      READ(5,1000) HED
1000  FORMAT(3A10)
      READ(5,1005) XMASS,STIFF,PK,DAMP1,DAMP2,DELTAT,XOUT,FY
1005  FORMAT(8F10.2)
      IF (XOUT.EQ.0.D0) XOUT=1.D0
C
C     READ LOAD INFORMATION
C
      READ(5,1015) KOUNT,DT,FACTOR,fmt
1015  FORMAT(1I5,2F10.2,a20)
      IF (FACTOR.EQ.0.D0) FACTOR=1.D0
      IF (DT.NE.0.D0) GO TO 30
      READ(5,FMT) (TT(I),PP(I),I=1,KOUNT)
      GO TO 40
30    TT(1)=0.D0
      DO 35 I=2,KOUNT
        TT(I)=I*DT
35    CONTINUE
      READ(5,fmt) (PP(I),I=1,KOUNT)
C
40    DOUT=XOUT*DELTAT
C      NOUT=(TT(KOUNT)-TT(1))/DOUT
C
C     RESPONSE CALCULATION
C
      CALL RESPON(DELTAT)
C
C
      STOP
      END
C
      SUBROUTINE RESPON(DELTA)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
C
C     CALCULATE THE RESPONSE TIME HISTORIES
C
      CHARACTER*10 HED
      COMMON /BLK5/ DF,FC,FT,FY,FYC1,FYT1,UC,UT,KEY,KEY0
      COMMON /BLK1/ XMASS,STIFF,PSTIFF,ST,FACTOR,C1,C2,HED
      COMMON /BLK2/ DAMP1,DOUT,PK,DAMP2,KOUNT
      COMMON /BLK3/ DELTAT,P1,P2,DP,U1,U2,F1,F2,T1,T2,V1,V2,A1,A2
      COMMON /BLK8/ RU,F1C,F2C
      COMMON /BLK4/ GA1,GA2,GV1,GV2,EI,ES,EH,ED,EK,ET,UB,UR,EKS,EKT
      COMMON /BLK7/ KPR
      COMMON /ACCL/ TT(2000),GA(2000)
      COMMON /RESP/ UU(100000),VV(100000),AA(100000),RR(100000),
     1              TO(100000),CC(100000)
      COMMON /BASE1/ BB(100000),GV(100000),SS(100000),KD(100000)
      COMMON /BLK9/ BSMAX,BSMIN,DISMAX,DISMIN,EDMAX,EIMAX,
     1              EKSMAX,EKTMAX
      COMMON /TIME/ TBSMAX,TBSMIN,TDIMAX,TDIMIN,TEDMAX,TEIMAX,
     1              TESMAX,TETMAX

C
C     COMPUTE MISCELLANEOUS CONSTANTS
C
      W1     =DSQRT(STIFF/XMASS)
      PERIOD1=8.D0*ATAN(1.0)/W1
      C1     =2.D0*W1*XMASS*DAMP1

      PSTIFF=PK*STIFF
```

```
      W2     =DSQRT(PSTIFF/XMASS)
      PERIOD2=8.D0*ATAN(1.0)/W2
      C2     =2.D0*W2*XMASS*DAMP2

C    YIELDING DISPL.
      FT=FY
      FC=-FY
      UT=FT/STIFF
      UC=FC/STIFF

C    ELASTO-PLASTIC YIELDING FORCE
      FYT1=UT*(STIFF-PSTIFF)
      FYC1=UC*(STIFF-PSTIFF)
      DF=FT-FC

C
C     ECHO-PRINT INPUT QUANTITIES
C
      WRITE(1,2068)
      WRITE(6,2000) HED
      WRITE(6,2005) XMASS,STIFF,PK,W1,PERIOD1,DAMP1,W2,PERIOD2,
     1              DAMP2
      WRITE(6,2020) DELTA,DOUT
      WRITE(6,2030) FACTOR
      WRITE(6,2035)
      WRITE(6,2045) (TT(I),GA(I),I=1,KOUNT)
C
      WRITE(6,2055) HED
      WRITE(6,2060)
C
C     INITIALIZE
C

      BSMAX=0.D0
      BSMIN=0.D0
      DISMAX=0.D0
      DISMIN=0.D0
      EDMAX=0.D0
      EIMAX=0.D0
      EKSMAX=0.D0
      EKTMAX=0.D0

      TBSMAX=0.D0
      TBSMIN=0.D0
      TDIMAX=0.D0
      TDIMIN=0.D0
      TEDMAX=0.D0
      TEIMAX=0.D0
      TESMAX=0.D0
      TETMAX=0.D0

      RU=0.D0
      MCYC=500
      KODY=1
      KPR=0
      A1=-GA(1)*FACTOR
      EI=0.D0
      EKT=0.D0
      ED=0.D0
      ES=0.D0
      EH=0.D0
      ET=0.D0
C
      GA1=GA(1)*FACTOR
      GA2=0.D0
      GV1=0.D0
```

```
      GV2=0.D0
      BS1=0.D0
      BS2=0.D0
      P1=-XMASS*FACTOR*GA(1)
      C=C2
      T1=TT(1)
C
      F1=0.D0
      F2=0.D0
      F1C=0.D0
      F2C=0.D0
      U1=0.D0
      U2=0.D0
      V1=0.D0
      V2=0.D0
      II=1
      KK=1
      KEY=0
C
C     COMPUTE RESPONSE HISTORY
C     (A) DETERMINING THE CURRENT INTEGRATION STEP
C         SIZE AT BEGINNING
C
      DT=DELTAT
      IF (DT.GT.(TT(2)-TT(1))) DT=TT(2)-TT(1)
      DELTAT=DT
      T2=T1+DT
      KCHEK=0
      KODP=KODY
      KEY0=KEY
C
C     STARTING PLACE EXCEPT THE FIRST TIME STEP
C     (B) UPDATING THE CURRENT INPUT-EXCITATION
C         DIGITIZATION INTERVAL AT WHICH THE CURRENT
C         INTEGRATION STEP RESIDES
C
20    IF (T2.LE.TT(II)) GO TO 25
      IF (T2.GT.TT(II).AND.T2.LE.TT(II+1)) GO TO 30
      KCHEK=0
      II=II+1
      IF (II.GE.KOUNT) GO TO 400
      GO TO 20
25    II=II-1
      GO TO 20
C
C     (C) INTERPOLATED LOADS AT THE TWO ENDS OF
C         CURRENT INTEGRATION STEP
C
30    IF (KCHEK) 35,35,40
35    TP=TT(II)
      TQ=TT(II+1)
      AP=GA(II)*FACTOR
      AQ=GA(II+1)*FACTOR
      DGR=(AQ-AP)/(TQ-TP)
      DP=-XMASS*DGR
      KCHEK=1
C
40    P2=-XMASS*(AP+DGR*(T2-TP))
C
      DGA=DGR*DT
      GA2=GA1+DGA
      DGV=GA1*DT+DGA*DT/2.0
      GV2=GV1+DGV
      DGU=GV1*DT+GA1*DT*DT/2.0+DGA*DT*DT/4.0
      IF (GV1.EQ.0.D0.OR.GV1.EQ.GV2) GO TO 90
      DTG=GV1/(GV1-GV2)*DT
```

```
      IF (DTG.GE.DT.OR.DTG.LE.0.D0) GO TO 90
      DT=DTG
      T2=T1+DTG
      P2=-XMASS*(AP+DGR*(T2-TP))
      DGA=DGR*DT
      GA2=GA1+DGA
      DGV=GA1*DT+DGA*DT/2.0
      GV2=GV1+DGV
      DGU=GV1*DT+GA1*DT*DT/2.0+DGA*DT*DT/4.0
      GV2=0.D0
C
C     CALCULATE RESPONSE AT THE END OF CURRENT
C     INTEGRATION TIME STEP
C
90    CALL SOLVE(DT,DA2,C)
      CALL BASE(BS2,C,DA2,DT,DU)
         U2=U1+DU
         DV=A1*DT+DA2*DT/2.0
         V2=V1+DV




C
C     Overshooting the time when V2=0
C
      U2=U1+DU
      DV=A1*DT+DA2*DT/2.0
      V2=V1+DV
      IF (V2.EQ.0.D0) GO TO 153
      IF ((V1*V2).GE.0.D0) GO TO 153
      NCYC=0
      DTP=0.D0
      DTQ=DT
      VP=V1
C
9100  DT=0.5D0*(DTP+DTQ)
      CALL SOLVE(DT,DA2,C)
      CALL BASE(BS2,C,DA2,DT,DU)

      U2=U1+DU
      DV=A1*DT+DA2*DT/2.0
      V2=V1+DV
      IF (DABS(V2).LE.0.001D0.OR.DABS(DTP-DTQ).LE.0.00001D0) THEN

        V2=0.D0
        GO TO 153
      ENDIF
      NCYC=NCYC+1
      IF (NCYC.LE.MCYC) GO TO 9105
      WRITE(*,995)
995   FORMAT(' COULD NOT COMPUTE THE OVER SHOOT FACTOR WITHIN',
     1       ' PERMISSIBLE NO. OF ITERATIONS')
      STOP
C
9105  IF ((VP*V2).GT.0.D0) GO TO 9110
      DTQ=DT
      GO TO 9100
9110  DTP=DT
      VP=V2
      GO TO 9100
```

```
C
C     Overshooting the time BS2=0
c

153   IF (BS2.EQ.0.D0) GO TO 125
      IF ((BS1*BS2).GE.0.D0) GO TO 125
      NCYC=0
      DTP=0.D0
      DTQ=DT
      BSP=BS1
C
100   DT=0.5D0*(DTP+DTQ)
      CALL SOLVE(DT,DA2,C)
      CALL BASE(BS2,C,DA2,DT,DU)
         U2=U1+DU
         DV=A1*DT+DA2*DT/2.0
         V2=V1+DV
      IF (DABS(BS2).LE.0.01D0.OR.DABS(DTP-DTQ).LE.0.00001D0) THEN
        BS2=0.D0
        F2=-F2C
        GO TO 120
      ENDIF
      NCYC=NCYC+1
      IF (NCYC.LE.MCYC) GO TO 105
      WRITE(*,95)
95    FORMAT(' COULD NOT COMPUTE THE OVER SHOOT FACTOR WITHIN',
     1        ' PERMISSIBLE NO. OF ITERATIONS')
      STOP
C
105   IF ((BSP*BS2).GT.0.D0) GO TO 110
      DTQ=DT
      GO TO 100
110   DTP=DT
      BSP=BS2
      GO TO 100

C
120   GA2=GA1+DGR*DT
      GV2=GV1+(GA1+GA2)*DT/2.D0
      T2=T1+DT
125   P2=P1+DP*DT
C
C
      RU=0.D0
      IF ((KEY.EQ.KEY0) .AND. (KEY.NE.O)) RU=DU
C
C
      CALL STATE(KODY,KODP,C,SG)
C
      IF (KODP.EQ.KODY) GO TO 140
C
C     FROM LOW STIFFNESS TO HIGH STIFFNESS
C
      IF (KODP.EQ.1.AND.KODY.EQ.0) THEN
         FCP=F2C
         F2C=V2*C1
         AP=A1+DA2
         EI=EI+(GA1+A1 + GA2+AP)*XMASS*DGU/2.0

         A2=(P2-F2C-F2)/XMASS
         ET=ET+(F1+F2)*DU/2.D0
         ED=ED+(F1C+FCP)*DU/2.D0

         DU=0.D0
         DGU=0.D0
```

```
C
          GO TO 150
      ENDIF



C
C     FROM HIGH STIFFNESS TO LOW STIFFNESS
C
      FCP=F2C

      F2C=V2*C2
      AP=A1+DA2
      EI=EI+(GA1+A1 + GA2+AP)*XMASS*DGU/2.0


      A2=(P2-F2C-F2)/XMASS
C     ACOR=(FP+FCP-F2C-F2)/XMASS
      ET=ET+(F1+F2)*DU/2.D0
      ED=ED+(F1C+FCP)*DU/2.D0

      DU=0.D0
      DGU=0.D0
      GO TO 150
C
140   A2=A1+DA2
150   CALL ENERGY(XMASS,ST,C,DU,DGU,DT,PSTIFF,STIFF)
C
C     PROCEED TO OUTPUT
C
      IF (KPR.NE.10) GO TO 155
      WRITE(6,2070) T2,KK,EI,EK,ED,ES,EH,UB,UR,GA2,GV2
      WRITE(7,3068) T2,U2,V2,A2,F2,EI,EK,ED,ES,EH,EKS
      WRITE(11,3068) T2,U2
      WRITE(15,3068) T2,EI
      WRITE(21,3068) U2,F2
      WRITE(17,3068) T2,ED
      WRITE(2,3068) T2,EKS
      WRITE(18,3068) T2,EKT
      KPR=0

C  Calculate maximum value
      IF (U2.GT.DISMAX) THEN
        DISMAX=U2
        TDIMAX=T2
      ENDIF
      IF (U2.LT.DISMIN) THEN
        DISMIN=U2
        TDIMIN=T2
      ENDIF

      IF (ED.GT.EDMAX) THEN
        EDMAX=ED
        TEDMAX=T2
      ENDIF

      IF (EI.GT.EIMAX) THEN
        EIMAX=EI
        TEIMAX=T2
      ENDIF

      IF (EKS.GT.EKSMAX) THEN
        EKSMAX=EKS
        TESMAX=T2
      ENDIF
```

```
      IF (EKT.GT.EKTMAX) THEN
        EKTMAX=EKT
        TETMAX=T2
      ENDIF

C
C     UPDATING INTEGRATION TIME STEP AND STRUCTURAL
C     RESPONSE QUANTITIES FOR THE NEXT TIME STEP
C
155   F1=F2
      F1C=F2C
      BS2=F2+F2C
      BS1=BS2
C
      P1=P2
      T1=T2
C
      A1=A2
      V1=V2
      U1=U2
C
      GA1=GA2
      GV1=GV2
C
      TO(KK)=T2
      UU(KK)=U2
      VV(KK)=V2
      AA(KK)=A2
      RR(KK)=F2
      CC(KK)=F2C
C
      BB(KK)=BS2
      GV(KK)=GV2
      SS(KK)=SG
      KD(KK)=KODY
C
      DT=DELTAT
      DTT=TT(II+1)-T1
      IF (DTT.EQ.0.D0) GO TO 160
      IF (DT.GT.DTT) DT=DTT
160   T2=T1+DT
      KODP=KODY
      KEY0=KEY
      KK=KK+1
      GO TO 20
C
C     PRINT RESPONSE TIME HISTORY AND SUMMARIES
C
400   WRITE(6,2090)
      WRITE(6,2095) (TO(I),UU(I),VV(I),AA(I),RR(I),I=1,KK,10)
C
      WRITE(6,2100)
      WRITE(6,2105) (TO(I),BB(I),GV(I),SS(I),KD(I),I=1,KK,10)
C

      WRITE (20,3068) TBSMAX,BSMAX
      WRITE (20,3068) TBSMIN,BSMIN
      WRITE (20,3068) TDIMAX,DISMAX
      WRITE (20,3068) TDIMIN,DISMIN
      WRITE (20,3068) TEDMAX,EDMAX
      WRITE (20,3068) TEIMAX,EIMAX
      WRITE (20,3068) TESMAX,EKSMAX
      WRITE (20,3068) TETMAX,EKTMAX

2000  FORMAT(1H ,52(1H-),/,
```

```
    1      53H DYNAMIC RESPONSE OF SINGLE DEGREE OF FREEDOM SYSTEMS,/,
    2       1H ,52(1H-),//,1H ,8A10)
2005  FORMAT(19H SYSTEM DESCRIPTION,/,1H ,42(1H-),/,
    1       29H  MASS .................... ,E14.6,/,
    2       29H  STIFFNESS ............... ,E14.6,/,
    3       29H  STRAIN HARDENING RATIO ... ,E14.6,/,
    4       29H  NATURAL FREQUENCY ........ ,E14.6,/,
    5       29H  PERIOD .................. ,E14.6,/,
    6       29H  DAMPING ................. ,E14.6,/,
    7       29H  SHIFT NATURAL FREQUENCY... ,E14.6,/,
    8       29H  SHIFT PERIOD............. ,E14.6,/,
    9       29H  SHIFT DAMPING ........... ,E14.6)
2020  FORMAT(24H SOLUTION SPECIFICATIONS,/,1H ,42(1H-),/,
    1       29H  ANALYSIS TIME STEP ....... ,E14.6,/,
    2       29H    OUTPUT TIME STEP ....... ,E14.6,/)
2030  FORMAT(1H ,15(1H-),/,16H LOADING HISTORY,/,1H ,15(1H-),//,
    1      15H LOAD FACTOR = ,E14.6)
2035  FORMAT(//,4(10X,4HTIME,2X,12HACCELERATION))
2045  FORMAT(4(5X,F9.4,2X,E12.5))
2055  FORMAT(1H ,8A10)
2060  FORMAT(' ENERGY TIME HISTORY'/,
    1       '   TIME    STEPS      INPUT     KINETIC     DAMPING   ',
    2       '   STRAIN      HYSTE.     UNBAL.  EQUILIBRIUM     ',
    3       'GROUND        GROUND       GROUND'/,
    4       '              NO.       ENERGY       ENERGY       ENERGY   ',
    5       '   ENERGY       ENERGY      ENERGY      RATIO     ',
    6       'ACCELERATION   VELOCITY   DISPLACEMENT'/,1X,140(1H-))
2068  FORMAT(' OUTPUT TIME HISTORIES IN THE ORDER? TIME,',
    1       'DISPLACEMENT, VELOCITY, ACCELERATION, RESISTANCE,',
    2       'INPUT ENERGY,'/,' KINETIC ENERGY, HYSTERETIC ENERGY,',
    3       'DAMPING ENERGY, HYSTERETIC ENERGY DUCTILITY,',
    4       'RESIDUAL DUCTILITY.,'//)
2070  FORMAT(F8.4,I7,6F12.4,F12.6,3F13.4)
3068  FORMAT(F8.4,11F12.5)
2090  FORMAT(' RESPONSE TIME HISTORY'/,
    1       '     TIME        DISPLACEMENT        VELOCITY        ',
    2       'ACCELERATION      RESISTANCE'/,1X,78(1H-))
2095  FORMAT(F9.5,5X,F12.4,5X,F12.4,5X,F12.4,5X,F12.4)
2100  FORMAT(' BASE-SHEAR TIME HISTORY'/,
    1       '     TIME         BASE-SHEAR    GROUND-VELOCITY      ',
    2       '    SIGN             KODY'/,1X,77(1H-))
2105  FORMAT(F9.5,3F17.4,I14)
C


      RETURN
      END
C
      SUBROUTINE SOLVE(DT,DA,C)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      CHARACTER*10 HED
      COMMON /BLK5/ DF,FC,FT,FY,FYC1,FYT1,UC,UT,KEY,KEY0
      COMMON /BLK1/ XMASS,STIFF,PSTIFF,ST,FACTOR,C1,C2,HED
      COMMON /BLK3/ DELTAT,P1,P2,DP,U1,U2,F1,F2,T1,T2,V1,V2,A1,A2
      COMMON /BLK8/ RU,F1C,F2C
C
      ST = STIFF
      IF (KEY .EQ.-1) ST=PSTIFF
      IF (KEY .EQ. 1) ST=PSTIFF

      EFMAS=XMASS+C*DT/2.D0+ST*DT*DT/4.D0
      EFLOD=(DP-C*A1-ST*(V1+A1*DT/2.D0))*DT
      DA=EFLOD/EFMAS
      DV=A1*DT+DA*DT/2.D0
      DU=V1*DT+A1*DT*DT/2.D0+DA*DT*DT/4.D0
```

```
C
      VV=V1+DV
      IF (KEY .EQ. 0) RR=FT-(UT-U1-DU)*(STIFF)
      IF (KEY .EQ. 1) RR=FYT1+PSTIFF*(U1+DU)
      IF (KEY .EQ. -1)RR=FYC1+PSTIFF*(U1+DU)

      AA=(P1+DP*DT-C*VV-RR)/XMASS
      DA=AA-A1
      DV=A1*DT+DA*DT/2.D0
      V2=V1+DV
      DU=V1*DT+A1*DT*DT/2.D0+DA*DT*DT/4.D0
      U2=U1+DU

      IF (U2.GT.UC .AND. U2.LT.UT) KEY=0.0
      IF (U2.GE.UT) THEN
         IF (V2 .GT. 0.0) KEY=1
         IF (V2 .LE. 0.0) THEN
            KEY=0
            UT=U2
            UC=U2-(FT-FC)/STIFF
            FT=FYT1+UT*PSTIFF
            FC=FT-DF
         ENDIF
      ENDIF

      IF (U2.LE.UC) THEN
         IF (V2 .LT. 0.0)   KEY=-1
         IF (V2 .GE. 0.0) THEN
            KEY=0
            UC=U2
            UT=U2+(FT-FC)/STIFF
            FC=FYC1+UC*PSTIFF
            FT=FC+DF
         ENDIF
       ENDIF
C************************************

C
      RETURN
      END
C
      SUBROUTINE BASE(BS,C,DA,DT,DU)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      CHARACTER*10 HED
      COMMON /BLK5/ DF,FC,FT,FY,FYC1,FYT1,UC,UT,KEY,KEY0
      COMMON /BLK1/ XMASS,STIFF,PSTIFF,ST,FACTOR,C1,C2,HED
      COMMON /BLK3/ DELTAT,P1,P2,DP,U1,U2,F1,F2,T1,T2,V1,V2,A1,A2
      COMMON /BLK8/ RU,F1C,F2C
C
      DV=A1*DT+DA*DT/2.D0
      DU=V1*DT+A1*DT*DT/2.D0+DA*DT*DT/4.D0

C
      IF (KEY .EQ. 0) F2=FT-(UT-U1-DU)*(STIFF)
      IF (KEY .EQ. 1) F2=FYT1+PSTIFF*(U1+DU)
      IF (KEY .EQ. -1)F2=FYC1+PSTIFF*(U1+DU)

      F2C=F1C+C*DV
      BS=F2+F2C
      RETURN
      END
C
      SUBROUTINE ENERGY(XMASS,ST,C,DU,DGU,DT,PSTIFF,STIFF)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      COMMON /BLK5/ DF,FC,FT,FY,FYC1,FYT1,UC,UT,KEY,KEY0
      COMMON /BLK2/ DAMP1,DOUT,PK,DAMP2,KOUNT
```

```
      COMMON /BLK3/ DELTAT,P1,P2,DP,U1,U2,F1,F2,T1,T2,V1,V2,A1,A2
      COMMON /BLK8/ RU,F1C,F2C
      COMMON /BLK4/ GA1,GA2,GV1,GV2,EI,ES,EH,ED,EK,ET,UB,UR,EKS,EKT

C
C     COMPUTE TIME HISTORY OF ENERGY INPUT, STORED , AND DISSIPATED
C     BY SINGLE DEGREE OF FREEDOM SYSTEM WITH STRAIN HARDENING
C
C     RECOVERABLE STRAIN ENERGY (ES), HYSTERETIC ENERGY (EH), DAMPING
C     ENERGY (ED) AND KINETIC ENERGY (EK)
C
      AT1=A1+GA1
      AT2=A2+GA2
      EI=EI+(AT1+AT2)*XMASS*DGU/2.0

      ED=ED+(F1C+F2C)*DU/2.D0
      ET=ET+(F1+F2)*DU/2.D0
      ES=ES+(F1+F2)*DU/2.D0-DABS(RU)*FYT1

      EH=ET-ES
      VT=GV2+V2
      EK=0.5D0*XMASS*VT*VT
      EKS=ES+EK
      EKT=ET+EK
C
C     COMPUTE ENERGY OUT-OF-BALANCE RATIO
C
      UB=EI-ES-EH-ED-EK
      UR=UB/EI

      WRITE(*,1000) T2,EI,EK,ED,ES,EH,UB,UR
1000  FORMAT(10F12.5)
C
      RETURN
      END
C

      SUBROUTINE STATE(KODY,KODP,C,SQ)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      CHARACTER*10 HED
      COMMON /BLK1/ XMASS,STIFF,PSTIFF,ST,FACTOR,C1,C2,HED
      COMMON /BLK3/ DELTAT,P1,P2,DP,U1,U2,F1,F2,T1,T2,V1,V2,A1,A2
      COMMON /BLK8/ RU,F1C,F2C
      COMMON /BLK4/ GA1,GA2,GV1,GV2,EI,ES,EH,ED,EK,ET,UB,UR,EKS,EKT
      COMMON /BLK7/ KPR
      COMMON /BLK9/ BSMAX,BSMIN,DISMAX,DISMIN,EDMAX,EIMAX,
     1              EKSMAX,EKTMAX
      COMMON /TIME/ TBSMAX,TBSMIN,TDIMAX,TDIMIN,TEDMAX,TEIMAX,
     1              TESMAX,TETMAX


C
      TEMP1=F1+F1C
      TEMP2=F2+F2C
      SP=TEMP1*V1
      SQ=TEMP2*V2
C
      IF (SP) 10,100,200
10    IF (SQ) 20,30,40
20    KODY=1
      ST=PSTIFF
      C=C2
      GO TO 400
30    KODY=0
      ST=STIFF
      C=C1
```

```
      IF (TEMP2.EQ.0.D0.AND.V2.EQ.0.D0) THEN
        KODY=1
        ST=PSTIFF
        C=C2
      ENDIF
      GO TO 400
40    KODY=0
      ST=STIFF
      C=C1
      GO TO 400
C
100   IF (SQ) 120,130,140
120   KODY=1
      ST=PSTIFF
      C=C2
      GO TO 400
130   KODY=0
      ST=STIFF
      C=C1
      IF (TEMP1.GE.0.D0.AND.TEMP2.GE.0.D0.AND.V1.GE.0.D0.AND.V2.GE.
     +  0.D0) THEN
             KODY=1
             ST=PSTIFF
             C=C2
      ENDIF
      IF (TEMP1.LE.0.D0.AND.TEMP2.LE.0.D0.AND.V1.LE.0.D0.AND.V2.LE.
     +  0.D0) THEN
             KODY=1
             ST=PSTIFF
             C=C2
      ENDIF
      GO TO 400
140   KODY=0
      ST=STIFF
      C=C1
      GO TO 400
C
200   IF (SQ) 220,230,240
220   KODY=1
      ST=PSTIFF
      C=C2
      GO TO 400
230   KODY=1
      ST=PSTIFF
      C=C2
      IF (TEMP1.GE.0.D0.AND.TEMP2.EQ.0.D0.AND.V1.GE.0.D0.AND.V2.EQ.
     +  0.D0) THEN
             KODY=0
             ST=STIFF
             C=C1
      ENDIF
      IF (TEMP1.LE.0.D0.AND.TEMP2.EQ.0.D0.AND.V1.LE.0.D0.AND.V2.EQ.
     +  0.D0) THEN
             KODY=0
             ST=STIFF
             C=C1
      ENDIF
      GO TO 400
240   KODY=0
      ST=STIFF
      C=C1
C
400   KPR=KPR+1
      IF (KPR.NE.10) GO TO 700
      KKKK=1
      IF (KODY.EQ.1) KKKK=-1
```

```
      WRITE(12,750) T2,TEMP2
      WRITE(13,750) T2,GV2
      WRITE(14,600) T2,KKKK

      IF (TEMP2.GT.BSMAX) THEN
        BSMAX=TEMP2
        TBSMAX=T2
      ENDIF
      IF (TEMP2.LT.BSMIN) THEN
        BSMIN=TEMP2
        TBSMIN=T2
      ENDIF


600   FORMAT(F15.3,I5)
C
700   WRITE(10,750) T2,F1,GV1,F2,GV2,KODP,KODY
750   FORMAT(5F15.3,2I5)
C
      RETURN
      END
```

```
C        PROGRAM FOR I-B
C        ***  Use Vrel* BS for controlling
C             (HERE THE STIFFNESS ONLY HAVE TWO VALUES)
C
C************************************************************

      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      CHARACTER*20 FMT
      CHARACTER*10 HED
C
C     DYNAMIC ANALYSIS OF SINGLE DEGREE OF FREEDOM SYSTEMS
C     WITH THE FOLLOWING FORCE-DEFORMATION MECHANICAL CHARACTERISTICS
C      SIGN BASE-SHEAR .EQ. SIGN GROUND VELOCITY : MIN.STIFFNESS
C      SIGN BASE-SHEAR .NE. SIGN GROUND VELOCITY : MAX.STIFFNESS
C
C     PROGRAMMED BY JODI FIRMANSJAH, CORRECTED AND EXPANDED BY I-HONG CHEN
C
C     SOME KEY VARIABLES
C       XMASS      =  MASS
C       STIFF      =  MAXIMUM STIFFNESS
C       PK         =  RATIO OF MINIMUM STIFFNESS TO MAXIMUM STIFFNESS
C       DAMP1      =  DAMPING RATIO OF MAXIMUN STIFFNESS SYSTEM
C       DAMP2      =  DAMPING RATIO OF MINIMUM STIFFNESS SYSTEM
C       DELTAT     =  INTEGRATION INTERVAL
C       XOUT       =  OUTPUT INTERVAL
C
C       KOUNT      =  NO. GROUND ACCELERATION RECORD
C       FACTOR     =  MAGNIFICATION FACTOR
C
      COMMON /BLK1/ XMASS,STIFF,PSTIFF,FACTOR,C1,C2,HED
      COMMON /BLK2/ DAMP1,DOUT,PK,DAMP2,KOUNT
      COMMON /BLK3/ DELTAT,P1,P2,DP,U1,U2,F1,F2,T1,T2,V1,V2,A1,A2
      COMMON /BLK8/ RU,F1C,F2C
      COMMON /ACCL/ TT(2000),PP(2000)
      COMMON /RESP/ UU(100000),VV(100000),AA(100000),RR(100000),
     1              TO(100000),CC(100000)
      COMMON /BLK9/ BSMAX,BSMIN,DISMAX,DISMIN,EDMAX,EIMAX,
     1              EKSMAX,EKTMAX
      COMMON /TIME/ TBSMAX,TBSMIN,TDIMAX,TDIMIN,TEDMAX,TEIMAX,
     1              TESMAX,TETMAX

      CHARACTER*24 INP
C
C     OPEN EXTERNAL FILES
C
      WRITE(*,5)
5     FORMAT(' input file')
      READ(*,10) INP
10    FORMAT(a24)

C
      OPEN(5,FILE=INP)
      OPEN(6,FILE='out000.009')
      OPEN(1,FILE='file1000.009')
      OPEN(7,FILE='file7000.009')
      OPEN(10,FILE='state000.009')
      OPEN(11,FILE='dis000.009')
      OPEN(12,FILE='bs000.009')
      OPEN(13,FILE='gv000.009')
      OPEN(UNIT=14,FILE='sg000.009')
      OPEN(2,FILE='eks000.009')
      OPEN(18,FILE='ekt000.009')
      OPEN(17,FILE='ed000.009')
      OPEN(UNIT=15,FILE='ei000.009')
      OPEN(20,FILE='max000.009')
C
```

```
C     READ HEADING AND SYSTEM INFORMATION
C
      READ(5,1000) HED
1000  FORMAT(3A10)
      READ(5,1005) XMASS,STIFF,PK,DAMP1,DAMP2,DELTAT,XOUT
1005  FORMAT(7F10.2)
      IF (XOUT.EQ.0.D0) XOUT=1.D0
C
C     READ LOAD INFORMATION
C
      READ(5,1015) KOUNT,DT,FACTOR,fmt
1015  FORMAT(1I5,2F10.2,a20)
      IF (FACTOR.EQ.0.D0) FACTOR=1.D0
      IF (DT.NE.0.D0) GO TO 30
      READ(5,FMT) (TT(I),PP(I),I=1,KOUNT)
      GO TO 40
30    TT(1)=0.D0
      DO 35 I=2,KOUNT
        TT(I)=I*DT
35    CONTINUE
      READ(5,fmt) (PP(I),I=1,KOUNT)
C
40    DOUT=XOUT*DELTAT
C      NOUT=(TT(KOUNT)-TT(1))/DOUT
C
C     RESPONSE CALCULATION
C
      CALL RESPON(DELTAT)
C
C
      STOP
      END
C
      SUBROUTINE RESPON(DELTA)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
C
C     CALCULATE THE RESPONSE TIME HISTORIES
C
      CHARACTER*10 HED
      COMMON /BLK1/ XMASS,STIFF,PSTIFF,FACTOR,C1,C2,HED
      COMMON /BLK2/ DAMP1,DOUT,PK,DAMP2,KOUNT
      COMMON /BLK3/ DELTAT,P1,P2,DP,U1,U2,F1,F2,T1,T2,V1,V2,A1,A2
      COMMON /BLK8/ RU,F1C,F2C
      COMMON /BLK4/ GA1,GA2,GV1,GV2,EI,ES,EH,ED,EK,ET,UB,UR,EKS,EKT
      COMMON /BLK7/ KPR
      COMMON /ACCL/ TT(2000),GA(2000)
      COMMON /RESP/ UU(100000),VV(100000),AA(100000),RR(100000),
     1              TO(100000),CC(100000)
      COMMON /BASE1/ BB(100000),GV(100000),SS(100000),KD(100000)
      COMMON /BLK9/ BSMAX,BSMIN,DISMAX,DISMIN,EDMAX,EIMAX,
     1              EKSMAX,EKTMAX
      COMMON /TIME/ TBSMAX,TBSMIN,TDIMAX,TDIMIN,TEDMAX,TEIMAX,
     1              TESMAX,TETMAX

C
C     COMPUTE MISCELLANEOUS CONSTANTS
C
      W1     =DSQRT(STIFF/XMASS)
      PERIOD1=8.D0*ATAN(1.0)/W1
      C1     =2.D0*W1*XMASS*DAMP1

      PSTIFF=PK*STIFF
      W2     =DSQRT(PSTIFF/XMASS)
      PERIOD2=8.D0*ATAN(1.0)/W2
      C2     =2.D0*W2*XMASS*DAMP2
```

```
C
C     ECHO-PRINT INPUT QUANTITIES
C
      WRITE(1,2068)
      WRITE(6,2000) HED
      WRITE(6,2005) XMASS,STIFF,PK,W1,PERIOD1,DAMP1,W2,PERIOD2,
     1              DAMP2
      WRITE(6,2020) DELTA,DOUT
      WRITE(6,2030) FACTOR
      WRITE(6,2035)
      WRITE(6,2045) (TT(I),GA(I),I=1,KOUNT)
C
      WRITE(6,2055) HED
      WRITE(6,2060)
C
C     INITIALIZE
C

      BSMAX=0.D0
      BSMIN=0.D0
      DISMAX=0.D0
      DISMIN=0.D0
      EDMAX=0.D0
      EIMAX=0.D0
      EKSMAX=0.D0
      EKTMAX=0.D0

      TBSMAX=0.D0
      TBSMIN=0.D0
      TDIMAX=0.D0
      TDIMIN=0.D0
      TEDMAX=0.D0
      TEIMAX=0.D0
      TESMAX=0.D0
      TETMAX=0.D0

      RU=0.D0
      MCYC=500
      KODY=1
      KPR=0
      A1=-GA(1)*FACTOR
      EI=0.D0
      EKT=0.D0
      ED=0.D0
      ES=0.D0
      EH=0.D0
      ET=0.D0
C
      GA1=GA(1)*FACTOR
      GA2=0.D0
      GV1=0.D0
      GV2=0.D0
      BS1=0.D0
      BS2=0.D0
      P1=-XMASS*FACTOR*GA(1)
      ST=PSTIFF
      C=C2
      T1=TT(1)
C
      F1=0.D0
      F2=0.D0
      F1C=0.D0
      F2C=0.D0
      U1=0.D0
      U2=0.D0
      V1=0.D0
```

```
      V2=0.D0
      II=1
      KK=1
C
C     COMPUTE RESPONSE HISTORY
C     (A) DETERMINING THE CURRENT INTEGRATION STEP
C         SIZE AT BEGINNING
C
      DT=DELTAT
      IF (DT.GT.(TT(2)-TT(1))) DT=TT(2)-TT(1)
      DELTAT=DT
      T2=T1+DT
      KCHEK=0
      KODP=KODY
C
C     STARTING PLACE EXCEPT THE FIRST TIME STEP
C     (B) UPDATING THE CURRENT INPUT-EXCITATION
C         DIGITIZATION INTERVAL AT WHICH THE CURRENT
C         INTEGRATION STEP RESIDES
C
20    IF (T2.LE.TT(II)) GO TO 25
      IF (T2.GT.TT(II).AND.T2.LE.TT(II+1)) GO TO 30
      KCHEK=0
      II=II+1
      IF (II.GE.KOUNT) GO TO 400
      GO TO 20
25    II=II-1
      GO TO 20
C
C     (C) INTERPOLATED LOADS AT THE TWO ENDS OF
C         CURRENT INTEGRATION STEP
C
30    IF (KCHEK) 35,35,40
35    TP=TT(II)
      TQ=TT(II+1)
      AP=GA(II)*FACTOR
      AQ=GA(II+1)*FACTOR
      DGR=(AQ-AP)/(TQ-TP)
      DP=-XMASS*DGR
      KCHEK=1
C
40    P2=-XMASS*(AP+DGR*(T2-TP))
      DGA=DGR*DT
      GA2=GA1+DGA
      DGV=GA1*DT+DGA*DT/2.0
      GV2=GV1+DGV
      DGU=GV1*DT+GA1*DT*DT/2.0+DGA*DT*DT/4.0
      IF (GV1.EQ.0.D0.OR.GV1.EQ.GV2) GO TO 90
      DTG=GV1/(GV1-GV2)*DT
      IF (DTG.GE.DT.OR.DTG.LE.0.D0) GO TO 90
      DT=DTG
      T2=T1+DTG
      P2=-XMASS*(AP+DGR*(T2-TP))
      DGA=DGR*DT
      GA2=GA1+DGA
      DGV=GA1*DT+DGA*DT/2.0
      GV2=GV1+DGV
      DGU=GV1*DT+GA1*DT*DT/2.0+DGA*DT*DT/4.0
      GV2=0.D0

C
C     CALCULATE RESPONSE AT THE END OF CURRENT
C     INTEGRATION TIME STEP
C
90    CALL SOLVE(DT,DA2,ST,C)
      CALL BASE(BS2,ST,C,DA2,DT,DU)
```

```
C
C     Overshooting the time when V2=0
C
      U2=U1+DU
      DV=A1*DT+DA2*DT/2.0
      V2=V1+DV
      IF (V2.EQ.0.D0) GO TO 153
      IF ((V1*V2).GE.0.D0) GO TO 153
      NCYC=0
      DTP=0.D0
      DTQ=DT
      VP=V1
C
9100  DT=0.5D0*(DTP+DTQ)
      CALL SOLVE(DT,DA2,ST,C)
      CALL BASE(BS2,ST,C,DA2,DT,DU)
C CALL BASE SHOULD BE ABLE TO OMMIT

      U2=U1+DU
      DV=A1*DT+DA2*DT/2.0
      V2=V1+DV
      IF (DABS(V2).LE.0.001D0.OR.DABS(DTP-DTQ).LE.0.00001D0) THEN
        V2=0.D0
        GO TO 153
      ENDIF
      NCYC=NCYC+1
      IF (NCYC.LE.MCYC) GO TO 9105
      WRITE(*,995)
995   FORMAT(' COULD NOT COMPUTE THE OVER SHOOT FACTOR WITHIN',
     1       ' PERMISSIBLE NO. OF ITERATIONS')
      STOP
C
9105  IF ((VP*V2).GT.0.D0) GO TO 9110
      DTQ=DT
      GO TO 9100
9110  DTP=DT
      VP=V2
      GO TO 9100


C
C     Overshooting the time BS2=0
c
153   IF (BS2.EQ.0.D0) GO TO 125
      IF ((BS1*BS2).GE.0.D0) GO TO 125
      NCYC=0
      DTP=0.D0
      DTQ=DT
      BSP=BS1
C
100   DT=0.5D0*(DTP+DTQ)
      CALL SOLVE(DT,DA2,ST,C)
      CALL BASE(BS2,ST,C,DA2,DT,DU)
      U2=U1+DU
      DV=A1*DT+DA2*DT/2.0
      V2=V1+DV
      IF (DABS(BS2).LE.0.01D0.OR.DABS(DTP-DTQ).LE.0.00001D0) THEN
        BS2=0.D0
        F2=-F2C
        GO TO 120
      ENDIF
      NCYC=NCYC+1
      IF (NCYC.LE.MCYC) GO TO 105
      WRITE(*,95)
95    FORMAT(' COULD NOT COMPUTE THE OVER SHOOT FACTOR WITHIN',
     1       ' PERMISSIBLE NO. OF ITERATIONS')
```

```
      STOP
C
105   IF ((BSP*BS2).GT.0.D0) GO TO 110
      DTQ=DT
      GO TO 100
110   DTP=DT
      BSP=BS2
      GO TO 100
C
120   GA2=GA1+DGR*DT
      GV2=GV1+(GA1+GA2)*DT/2.D0
      T2=T1+DT
125   P2=P1+DP*DT
      CALL STATE(KODY,KODP,ST,C,SG)
C
      IF (KODP.EQ.KODY) GO TO 140
C
C    FROM LOW STIFFNESS TO HIGH STIFFNESS
C
      IF (KODP.EQ.1.AND.KODY.EQ.0) THEN
         RU=0.D0
         FCP=F2C
         F2C=V2*C1
         AP=A1+DA2
         EI=EI+(GA1+A1 + GA2+AP)*XMASS*DGU/2.0

         A2=(P2-F2C-F2)/XMASS
C     ACOR=(FP+FCP-F2C-F2)/XMASS
         ET=ET+(F1+F2)*DU/2.D0
         ED=ED+(F1C+FCP)*DU/2.D0

         DU=0.D0
         DGU=0.D0
C
         GO TO 150

      ENDIF



C
C     FROM HIGH STIFFNESS TO LOW STIFFNESS
C
      FP=F2
      FCP=F2C

      F2=U2 * PSTIFF
      F2C=V2*C2
      AP=A1+DA2
      EI=EI+(GA1+A1 + GA2+AP)*XMASS*DGU/2.0


      A2=(P2-F2C-F2)/XMASS
C     ACOR=(FP+FCP-F2C-F2)/XMASS
      ET=ET+(F1+FP)*DU/2.D0
      ED=ED+(F1C+FCP)*DU/2.D0

      RU=0.D0
      DU=0.D0
      DGU=0.D0
      GO TO 150
C
140   A2=A1+DA2
      IF(KODY.EQ.0.D0.AND.KODP.EQ.0.D0) RU=RU+DU
150   CALL ENERGY(XMASS,ST,C,DU,DGU,DT,PSTIFF,STIFF)
C
```

```
C     PROCEED TO OUTPUT
C
      IF (KPR.NE.10) GO TO 155
      WRITE(6,2070) T2,KK,EI,EK,ED,ES,EH,UB,UR,GA2,GV2
      WRITE(7,3068) T2,U2,V2,A2,F2,EI,EK,ED,ES,EH,EKS
      WRITE(11,3068) T2,U2
      WRITE(15,3068) T2,EI
      WRITE(17,3068) T2,ED
      WRITE(2,3068) T2,EKS
      WRITE(18,3068) T2,EKT
      KPR=0

C  Calculate maximum value
      IF (U2.GT.DISMAX) THEN
        DISMAX=U2
        TDIMAX=T2
      ENDIF
      IF (U2.LT.DISMIN) THEN
        DISMIN=U2
        TDIMIN=T2
      ENDIF

      IF (ED.GT.EDMAX) THEN
        EDMAX=ED
        TEDMAX=T2
      ENDIF

      IF (EI.GT.EIMAX) THEN
        EIMAX=EI
        TEIMAX=T2
      ENDIF

      IF (EKS.GT.EKSMAX) THEN
        EKSMAX=EKS
        TESMAX=T2
      ENDIF

      IF (EKT.GT.EKTMAX) THEN
        EKTMAX=EKT
        TETMAX=T2
      ENDIF

C
C     UPDATING INTEGRATION TIME STEP AND STRUCTURAL
C     RESPONSE QUANTITIES FOR THE NEXT TIME STEP
C
155   F1=F2
      F1C=F2C
      BS2=F2+F2C
      BS1=BS2
C
      P1=P2
      T1=T2
C
      A1=A2
      V1=V2
      U1=U2
C
      GA1=GA2
      GV1=GV2
C
      TO(KK)=T2
      UU(KK)=U2
      VV(KK)=V2
      AA(KK)=A2
      RR(KK)=F2
```

```
      CC(KK)=F2C
C
      BB(KK)=BS2
      GV(KK)=GV2
      SS(KK)=SG
      KD(KK)=KODY
C
      DT=DELTAT
      DTT=TT(II+1)-T1
      IF (DTT.EQ.0.D0) GO TO 160
      IF (DT.GT.DTT) DT=DTT
160   T2=T1+DT
      KODP=KODY
      KK=KK+1
      GO TO 20
C
C     PRINT RESPONSE TIME HISTORY AND SUMMARIES
C
400   WRITE(6,2090)
      WRITE(6,2095) (TO(I),UU(I),VV(I),AA(I),RR(I),I=1,KK,10)
C
      WRITE(6,2100)
      WRITE(6,2105) (TO(I),BB(I),GV(I),SS(I),KD(I),I=1,KK,10)
C

      WRITE (20,3068) TBSMAX,BSMAX
      WRITE (20,3068) TBSMIN,BSMIN
      WRITE (20,3068) TDIMAX,DISMAX
      WRITE (20,3068) TDIMIN,DISMIN
      WRITE (20,3068) TEDMAX,EDMAX
      WRITE (20,3068) TEIMAX,EIMAX
      WRITE (20,3068) TESMAX,EKSMAX
      WRITE (20,3068) TETMAX,EKTMAX

2000  FORMAT(1H ,52(1H-),/,
     1      53H DYNAMIC RESPONSE OF SINGLE DEGREE OF FREEDOM SYSTEMS,/,
     2       1H ,52(1H-),//,1H ,8A10)
2005  FORMAT(19H SYSTEM DESCRIPTION,/,1H ,42(1H-),/,
     1       29H  MASS ..................... ,E14.6,/,
     2       29H  STIFFNESS ................ ,E14.6,/,
     3       29H  STRAIN HARDENING RATIO ... ,E14.6,/,
     4       29H  NATURAL FREQUENCY ........ ,E14.6,/,
     5       29H  PERIOD ................... ,E14.6,/,
     6       29H  DAMPING .................. ,E14.6,/,
     7       29H  SHIFT NATURAL FREQUENCY... ,E14.6,/,
     8       29H  SHIFT PERIOD.............. ,E14.6,/,
     9       29H  SHIFT DAMPING ............ ,E14.6)
2020  FORMAT(24H SOLUTION SPECIFICATIONS,/,1H ,42(1H-),/,
     1       29H  ANALYSIS TIME STEP ....... ,E14.6,/,
     2       29H    OUTPUT TIME STEP ....... ,E14.6,/)
2030  FORMAT(1H ,15(1H-),/,16H LOADING HISTORY,/,1H ,15(1H-),//,
     1      15H LOAD FACTOR = ,E14.6)
2035  FORMAT(//,4(10X,4HTIME,2X,12HACCELERATION))
2045  FORMAT(4(5X,F9.4,2X,E12.5))
2055  FORMAT(1H ,8A10)
2060  FORMAT(' ENERGY TIME HISTORY'/,
     1       '   TIME    STEPS       INPUT     KINETIC     DAMPING   ',
     2       '   STRAIN      HYSTE.     UNBAL.  EQUILIBRIUM      ',
     3       'GROUND        GROUND        GROUND'/,
     4       '               NO.       ENERGY      ENERGY      ENERGY   ',
     5       '   ENERGY      ENERGY     ENERGY     RATIO      ',
     6       'ACCELERATION   VELOCITY   DISPLACEMENT'/,1X,140(1H-))
2068  FORMAT(' OUTPUT TIME HISTORIES IN THE ORDER? TIME,',
     1       'DISPLACEMENT, VELOCITY, ACCELERATION, RESISTANCE,',
     2       'INPUT ENERGY,'/,' KINETIC ENERGY, HYSTERETIC ENERGY,',
     3       'DAMPING ENERGY, HYSTERETIC ENERGY DUCTILITY,',
```

```
    4       'RESIDUAL DUCTILITY.,'//)
2070  FORMAT(F8.4,I7,6F12.4,F12.6,3F13.4)
3068  FORMAT(F8.4,11F12.5)
2090  FORMAT(' RESPONSE TIME HISTORY'/,
    1       '     TIME        DISPLACEMENT       VELOCITY         ',
    2       'ACCELERATION      RESISTANCE'/,1X,78(1H-))
2095  FORMAT(F9.5,5X,F12.4,5X,F12.4,5X,F12.4,5X,F12.4)
2100  FORMAT(' BASE-SHEAR TIME HISTORY'/,
    1       '     TIME          BASE-SHEAR    GROUND-VELOCITY     ',
    2       '    SIGN              KODY'/,1X,77(1H-))
2105  FORMAT(F9.5,3F17.4,I14)
C


      RETURN
      END
C
      SUBROUTINE SOLVE(DT,DA,ST,C)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      CHARACTER*10 HED
      COMMON /BLK1/ XMASS,STIFF,PSTIFF,FACTOR,C1,C2,HED
      COMMON /BLK3/ DELTAT,P1,P2,DP,U1,U2,F1,F2,T1,T2,V1,V2,A1,A2
      COMMON /BLK8/ RU,F1C,F2C
C
      EFMAS=XMASS+C*DT/2.D0+ST*DT*DT/4.D0
      EFLOD=(DP-C*A1-ST*(V1+A1*DT/2.D0))*DT
      DA=EFLOD/EFMAS
      DV=A1*DT+DA*DT/2.D0
      DU=V1*DT+A1*DT*DT/2.D0+DA*DT*DT/4.D0
C
      VV=V1+DV
      RR=F1+ST*DU
      AA=(P1+DP*DT-C*VV-RR)/XMASS
      DA=AA-A1
C
      RETURN
      END
C
      SUBROUTINE BASE(BS,ST,C,DA,DT,DU)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      CHARACTER*10 HED
      COMMON /BLK1/ XMASS,STIFF,PSTIFF,FACTOR,C1,C2,HED
      COMMON /BLK3/ DELTAT,P1,P2,DP,U1,U2,F1,F2,T1,T2,V1,V2,A1,A2
      COMMON /BLK8/ RU,F1C,F2C
C
      DV=A1*DT+DA*DT/2.D0
      DU=V1*DT+A1*DT*DT/2.D0+DA*DT*DT/4.D0
      F2=F1+ST*DU
      F2C=F1C+C*DV
      BS=F2+F2C

C
      RETURN
      END
C
      SUBROUTINE ENERGY(XMASS,ST,C,DU,DGU,DT,PSTIFF,STIFF)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      COMMON /BLK2/ DAMP1,DOUT,PK,DAMP2,KOUNT
      COMMON /BLK3/ DELTAT,P1,P2,DP,U1,U2,F1,F2,T1,T2,V1,V2,A1,A2
      COMMON /BLK8/ RU,F1C,F2C
      COMMON /BLK4/ GA1,GA2,GV1,GV2,EI,ES,EH,ED,EK,ET,UB,UR,EKS,EKT

C
C     COMPUTE TIME HISTORY OF ENERGY INPUT, STORED , AND DISSIPATED
C     BY SINGLE DEGREE OF FREEDOM SYSTEM WITH STRAIN HARDENING
```

```
C
C     RECOVERABLE STRAIN ENERGY (ES), HYSTERETIC ENERGY (EH), DAMPING
C     ENERGY (ED) AND KINETIC ENERGY (EK)
C
      AT1=A1+GA1
      AT2=A2+GA2
      EI=EI+(AT1+AT2)*XMASS*DGU/2.0

      ED=ED+(F1C+F2C)*DU/2.D0
      ET=ET+(F1+F2)*DU/2.D0
      ES=0.5*PSTIFF*U2*U2 + 0.5*(STIFF-PSTIFF)*RU*RU
      EH=ET-ES
      VT=GV2+V2
      EK=0.5D0*XMASS*VT*VT
      EKS=ES+EK
      EKT=ET+EK
C
C     COMPUTE ENERGY OUT-OF-BALANCE RATIO
C
      UB=EI-ES-EH-ED-EK
      UR=UB/EI

      WRITE(*,1000) T2,EI,EK,ED,ES,EH,UB,UR
1000  FORMAT(10F12.5)
C
      RETURN
      END
C
      SUBROUTINE STATE(KODY,KODP,ST,C,SQ)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      CHARACTER*10 HED
      COMMON /BLK1/ XMASS,STIFF,PSTIFF,FACTOR,C1,C2,HED

      COMMON /BLK3/ DELTAT,P1,P2,DP,U1,U2,F1,F2,T1,T2,V1,V2,A1,A2
      COMMON /BLK8/ RU,F1C,F2C
      COMMON /BLK4/ GA1,GA2,GV1,GV2,EI,ES,EH,ED,EK,ET,UB,UR,EKS,EKT
      COMMON /BLK7/ KPR
      COMMON /BLK9/ BSMAX,BSMIN,DISMAX,DISMIN,EDMAX,EIMAX,
     1              EKSMAX,EKTMAX
      COMMON /TIME/ TBSMAX,TBSMIN,TDIMAX,TDIMIN,TEDMAX,TEIMAX,
     1              TESMAX,TETMAX


C
      TEMP1=F1+F1C
      TEMP2=F2+F2C
      SP=TEMP1*V1
      SQ=TEMP2*V2
C
      IF (SP) 10,100,200
10    IF (SQ) 20,30,40
20    KODY=1
      ST=PSTIFF
      C=C2
      GO TO 400
30    KODY=0
      ST=STIFF
      C=C1
      IF (TEMP2.EQ.0.D0.AND.V2.EQ.0.D0) THEN
        KODY=1
        ST=PSTIFF
        C=C2
      ENDIF
      GO TO 400
40    KODY=0
      ST=STIFF
```

```
      C=C1
      GO TO 400
C
100   IF (SQ) 120,130,140
120   KODY=1
      ST=PSTIFF
      C=C2
      GO TO 400
130   KODY=0
      ST=STIFF
      C=C1
      IF (TEMP1.GE.0.D0.AND.TEMP2.GE.0.D0.AND.V1.GE.0.D0.AND.V2.GE.
     +  0.D0) THEN
             KODY=1
             ST=PSTIFF
             C=C2
      ENDIF
      IF (TEMP1.LE.0.D0.AND.TEMP2.LE.0.D0.AND.V1.LE.0.D0.AND.V2.LE.
     +  0.D0) THEN
             KODY=1
             ST=PSTIFF
             C=C2
      ENDIF
      GO TO 400
140   KODY=0
      ST=STIFF
      C=C1
      GO TO 400
C
200   IF (SQ) 220,230,240
220   KODY=1
      ST=PSTIFF
      C=C2
      GO TO 400
230   KODY=1
      ST=PSTIFF
      C=C2
      IF (TEMP1.GE.0.D0.AND.TEMP2.EQ.0.D0.AND.V1.GE.0.D0.AND.V2.EQ.
     +  0.D0) THEN
             KODY=0
             ST=STIFF
             C=C1
      ENDIF
      IF (TEMP1.LE.0.D0.AND.TEMP2.EQ.0.D0.AND.V1.LE.0.D0.AND.V2.EQ.
     +  0.D0) THEN
             KODY=0
             ST=STIFF
             C=C1
      ENDIF
      GO TO 400
240   KODY=0
      ST=STIFF
      C=C1
C
400   KPR=KPR+1
      IF (KPR.NE.10) GO TO 700
      KKKK=1
      IF (KODY.EQ.1) KKKK=-1
      WRITE(12,750) T2,TEMP2
      WRITE(13,750) T2,GV2
      WRITE(14,600) T2,KKKK

      IF (TEMP2.GT.BSMAX) THEN
        BSMAX=TEMP2
        TBSMAX=T2
      ENDIF
```

```
      IF (TEMP2.LT.BSMIN) THEN
        BSMIN=TEMP2
        TBSMIN=T2
      ENDIF


600   FORMAT(F15.3,I5)
C
700   WRITE(10,750) T2,F1,GV1,F2,GV2,KODP,KODY
750   FORMAT(5F15.3,2I5)
C
      RETURN
      END
```

```
C       PROGRAM FOR II-B
c      ===================Here keep damping constant ie c1=c2   ==============
c                         (ONLY CHANGE STIFFNESS STIFF & PSTIFF )
C
C        ***  Use Vrel* BS for controlling
C             (HERE THE STIFFNESS ONLY HAVE TWO VALUES)
C
C*************************************************************

      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      CHARACTER*20 FMT
      CHARACTER*10 HED
C
C     DYNAMIC ANALYSIS OF SINGLE DEGREE OF FREEDOM SYSTEMS
C     WITH THE FOLLOWING FORCE-DEFORMATION MECHANICAL CHARACTERISTICS
C      SIGN BASE-SHEAR .EQ. SIGN GROUND VELOCITY : MIN.STIFFNESS
C      SIGN BASE-SHEAR .NE. SIGN GROUND VELOCITY : MAX.STIFFNESS
C
C     PROGRAMMED BY JODI FIRMANSJAH, CORRECTED AND EXPANDED BY I-HONG CHEN
C
C     SOME KEY VARIABLES
C       XMASS     =  MASS
C       STIFF     =  MAXIMUM STIFFNESS
C       PK        =  RATIO OF MINIMUM STIFFNESS TO MAXIMUM STIFFNESS
C       DAMP1     =  DAMPING RATIO OF MAXIMUN STIFFNESS SYSTEM
C       DAMP2     =  DAMPING RATIO OF MINIMUM STIFFNESS SYSTEM
C       DELTAT    =  INTEGRATION INTERVAL
C       XOUT      =  OUTPUT INTERVAL
C
C       KOUNT     =  NO. GROUND ACCELERATION RECORD
C       FACTOR    =  MAGNIFICATION FACTOR
C
      COMMON /BLK1/ XMASS,STIFF,PSTIFF,FACTOR,C1,C2,HED
      COMMON /BLK2/ DAMP1,DOUT,PK,DAMP2,KOUNT
      COMMON /BLK3/ DELTAT,P1,P2,DP,U1,U2,F1,F2,T1,T2,V1,V2,A1,A2
      COMMON /BLK8/ RU,F1C,F2C
      COMMON /ACCL/ TT(2000),PP(2000)
      COMMON /RESP/ UU(100000),VV(100000),AA(100000),RR(100000),
     1              TO(100000),CC(100000)
      COMMON /BLK9/ BSMAX,BSMIN,DISMAX,DISMIN,EDMAX,EIMAX,
     1              EKSMAX,EKTMAX
      COMMON /TIME/ TBSMAX,TBSMIN,TDIMAX,TDIMIN,TEDMAX,TEIMAX,
     1              TESMAX,TETMAX

      CHARACTER*24 INP
C
C     OPEN EXTERNAL FILES
C
      WRITE(*,5)
5     FORMAT(' input file')
      READ(*,10) INP
10    FORMAT(a24)

C
      OPEN(5,FILE=INP)
      OPEN(6,FILE='out001')
      OPEN(1,FILE='file1001')
      OPEN(7,FILE='file7001')
      OPEN(10,FILE='state001')
      OPEN(11,FILE='dis001')
      OPEN(12,FILE='bs001')
      OPEN(13,FILE='gv001')
      OPEN(UNIT=14,FILE='sg001')
      OPEN(2,FILE='eks001')
      OPEN(18,FILE='ekt001')
      OPEN(17,FILE='ed001')
```

```
      OPEN(UNIT=15,FILE='ei001')
      OPEN(20,FILE='max001')
C
C     READ HEADING AND SYSTEM INFORMATION
C
      READ(5,1000) HED
1000  FORMAT(3A10)
      READ(5,1005) XMASS,STIFF,PK,DAMP1,DAMP2,DELTAT,XOUT
1005  FORMAT(7F10.2)
      IF (XOUT.EQ.0.D0) XOUT=1.D0
C
C     READ LOAD INFORMATION
C
      READ(5,1015) KOUNT,DT,FACTOR,fmt
1015  FORMAT(1I5,2F10.2,a20)
      IF (FACTOR.EQ.0.D0) FACTOR=1.D0
      IF (DT.NE.0.D0) GO TO 30
      READ(5,FMT) (TT(I),PP(I),I=1,KOUNT)
      GO TO 40
30    TT(1)=0.D0
      DO 35 I=2,KOUNT
        TT(I)=I*DT
35    CONTINUE
      READ(5,fmt) (PP(I),I=1,KOUNT)
C
40    DOUT=XOUT*DELTAT
C
C
C     RESPONSE CALCULATION
C
      CALL RESPON(DELTAT)
C
C
      STOP
      END
C
      SUBROUTINE RESPON(DELTA)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
C
C     CALCULATE THE RESPONSE TIME HISTORIES
C
      CHARACTER*10 HED
      COMMON /BLK1/ XMASS,STIFF,PSTIFF,FACTOR,C1,C2,HED
      COMMON /BLK2/ DAMP1,DOUT,PK,DAMP2,KOUNT
      COMMON /BLK3/ DELTAT,P1,P2,DP,U1,U2,F1,F2,T1,T2,V1,V2,A1,A2
      COMMON /BLK8/ RU,F1C,F2C
      COMMON /BLK4/ GA1,GA2,GV1,GV2,EI,ES,EH,ED,EK,ET,UB,UR,EKS,EKT
      COMMON /BLK7/ KPR
      COMMON /ACCL/ TT(2000),GA(2000)
      COMMON /RESP/ UU(100000),VV(100000),AA(100000),RR(100000),
     1              TO(100000),CC(100000)
      COMMON /BASE1/ BB(100000),GV(100000),SS(100000),KD(100000)
      COMMON /BLK9/ BSMAX,BSMIN,DISMAX,DISMIN,EDMAX,EIMAX,
     1              EKSMAX,EKTMAX
      COMMON /TIME/ TBSMAX,TBSMIN,TDIMAX,TDIMIN,TEDMAX,TEIMAX,
     1              TESMAX,TETMAX
C
C     COMPUTE MISCELLANEOUS CONSTANTS
C
      W1     =DSQRT(STIFF/XMASS)
      PERIOD1=8.D0*ATAN(1.0)/W1
      C1     =2.D0*W1*XMASS*DAMP1

      PSTIFF=PK*STIFF
      W2     =DSQRT(PSTIFF/XMASS)
      PERIOD2=8.D0*ATAN(1.0)/W2
```

```
C
C  LET C2 = C1
      C2     =2.D0*W1*XMASS*DAMP1
C
C     ECHO-PRINT INPUT QUANTITIES
C
      WRITE(1,2068)
      WRITE(6,2000) HED
      WRITE(6,2005) XMASS,STIFF,PK,W1,PERIOD1,DAMP1,W2,PERIOD2,
     1              DAMP2
      WRITE(6,2020) DELTA,DOUT
      WRITE(6,2030) FACTOR
      WRITE(6,2035)
      WRITE(6,2045) (TT(I),GA(I),I=1,KOUNT)
C
      WRITE(6,2055) HED
      WRITE(6,2060)
C
C     INITIALIZE
C

      BSMAX=0.D0
      BSMIN=0.D0
      DISMAX=0.D0
      DISMIN=0.D0
      EDMAX=0.D0
      EIMAX=0.D0
      EKSMAX=0.D0
      EKTMAX=0.D0

      TBSMAX=0.D0
      TBSMIN=0.D0
      TDIMAX=0.D0
      TDIMIN=0.D0
      TEDMAX=0.D0
      TEIMAX=0.D0
      TESMAX=0.D0
      TETMAX=0.D0

      RU=0.D0
      MCYC=500
      KODY=1
      KPR=0
      A1=-GA(1)*FACTOR
      EI=0.D0
      EKT=0.D0
      ED=0.D0
      ES=0.D0
      EH=0.D0
      ET=0.D0
C
      GA1=GA(1)*FACTOR
      GA2=0.D0
      GV1=0.D0
      GV2=0.D0
      BS1=0.D0
      BS2=0.D0
      P1=-XMASS*FACTOR*GA(1)
      ST=PSTIFF
      C=C2
      T1=TT(1)
C
      F1=0.D0
      F2=0.D0
      F1C=0.D0
      F2C=0.D0
```

```
      U1=0.D0
      U2=0.D0
      V1=0.D0
      V2=0.D0
      II=1
      KK=1
C
C     COMPUTE RESPONSE HISTORY
C     (A) DETERMINING THE CURRENT INTEGRATION STEP
C         SIZE AT BEGINNING
C
      DT=DELTAT
      IF (DT.GT.(TT(2)-TT(1))) DT=TT(2)-TT(1)
      DELTAT=DT
      T2=T1+DT
      KCHEK=0
      KODP=KODY
C
C     STARTING PLACE EXCEPT THE FIRST TIME STEP
C     (B) UPDATING THE CURRENT INPUT-EXCITATION
C         DIGITIZATION INTERVAL AT WHICH THE CURRENT
C         INTEGRATION STEP RESIDES
C
20    IF (T2.LE.TT(II)) GO TO 25
      IF (T2.GT.TT(II).AND.T2.LE.TT(II+1)) GO TO 30
      KCHEK=0
      II=II+1
      IF (II.GE.KOUNT) GO TO 400
      GO TO 20
25    II=II-1
      GO TO 20
C
C     (C) INTERPOLATED LOADS AT THE TWO ENDS OF
C         CURRENT INTEGRATION STEP
C
30    IF (KCHEK) 35,35,40
35    TP=TT(II)
      TQ=TT(II+1)
      AP=GA(II)*FACTOR
      AQ=GA(II+1)*FACTOR
      DGR=(AQ-AP)/(TQ-TP)
      DP=-XMASS*DGR
      KCHEK=1
C
40    P2=-XMASS*(AP+DGR*(T2-TP))
c
      DGA=DGR*DT
      GA2=GA1+DGA
      DGV=GA1*DT+DGA*DT/2.0
      GV2=GV1+DGV
      DGU=GV1*DT+GA1*DT*DT/2.0+DGA*DT*DT/4.0
      IF (GV1.EQ.0.D0.OR.GV1.EQ.GV2) GO TO 90
      DTG=GV1/(GV1-GV2)*DT
      IF (DTG.GE.DT.OR.DTG.LE.0.D0) GO TO 90
      DT=DTG
      T2=T1+DTG
      P2=-XMASS*(AP+DGR*(T2-TP))
      DGA=DGR*DT
      GA2=GA1+DGA
      DGV=GA1*DT+DGA*DT/2.0
      GV2=GV1+DGV
      DGU=GV1*DT+GA1*DT*DT/2.0+DGA*DT*DT/4.0
      GV2=0.D0

C
C     CALCULATE RESPONSE AT THE END OF CURRENT
```

```
C     INTEGRATION TIME STEP
C
90    CALL SOLVE(DT,DA2,ST,C)
      CALL BASE(BS2,ST,C,DA2,DT,DU)
C
C     Overshooting the time when V2=0
C
      U2=U1+DU
      DV=A1*DT+DA2*DT/2.0
      V2=V1+DV
      IF (V2.EQ.0.D0) GO TO 153
      IF ((V1*V2).GE.0.D0) GO TO 153
      NCYC=0
      DTP=0.D0
      DTQ=DT
      VP=V1
C
9100  DT=0.5D0*(DTP+DTQ)
      CALL SOLVE(DT,DA2,ST,C)
      CALL BASE(BS2,ST,C,DA2,DT,DU)

      U2=U1+DU
      DV=A1*DT+DA2*DT/2.0
      V2=V1+DV
      IF (DABS(V2).LE.0.001D0.OR.DABS(DTP-DTQ).LE.0.00001D0) THEN

        V2=0.D0
        GO TO 153
      ENDIF
      NCYC=NCYC+1
      IF (NCYC.LE.MCYC) GO TO 9105
      WRITE(*,995)
995   FORMAT(' COULD NOT COMPUTE THE OVER SHOOT FACTOR WITHIN',
     1       ' PERMISSIBLE NO. OF ITERATIONS')
      STOP
C
9105  IF ((VP*V2).GT.0.D0) GO TO 9110
      DTQ=DT
      GO TO 9100
9110  DTP=DT
      VP=V2
      GO TO 9100


C
C     Overshooting the time BS2=0
c
153   IF (BS2.EQ.0.D0) GO TO 125
      IF ((BS1*BS2).GE.0.D0) GO TO 125
      NCYC=0
      DTP=0.D0
      DTQ=DT
      BSP=BS1
C
100   DT=0.5D0*(DTP+DTQ)
      CALL SOLVE(DT,DA2,ST,C)
      CALL BASE(BS2,ST,C,DA2,DT,DU)
      U2=U1+DU
      DV=A1*DT+DA2*DT/2.0
      V2=V1+DV
      IF (DABS(BS2).LE.0.01D0.OR.DABS(DTP-DTQ).LE.0.00001D0) THEN
        BS2=0.D0
        F2=-F2C
        GO TO 120
      ENDIF
      NCYC=NCYC+1
```

```
      IF (NCYC.LE.MCYC) GO TO 105
      WRITE(*,95)
95    FORMAT(' COULD NOT COMPUTE THE OVER SHOOT FACTOR WITHIN',
     1        ' PERMISSIBLE NO. OF ITERATIONS')
      STOP
C
105   IF ((BSP*BS2).GT.0.D0) GO TO 110
      DTQ=DT
      GO TO 100
110   DTP=DT
      BSP=BS2
      GO TO 100
C
120   GA2=GA1+DGR*DT
      GV2=GV1+(GA1+GA2)*DT/2.D0
      T2=T1+DT
125   P2=P1+DP*DT
      CALL STATE(KODY,KODP,ST,C,SG)
C
      IF (KODP.EQ.KODY) GO TO 140
C
C    FROM LOW STIFFNESS TO HIGH STIFFNESS
C
      IF (KODP.EQ.1.AND.KODY.EQ.0) THEN
         RU=0.D0
         FCP=F2C
         F2C=V2*C1
         AP=A1+DA2
         EI=EI+(GA1+A1 + GA2+AP)*XMASS*DGU/2.0

         A2=(P2-F2C-F2)/XMASS
         ET=ET+(F1+F2)*DU/2.D0
         ED=ED+(F1C+FCP)*DU/2.D0

         DU=0.D0
         DGU=0.D0
C
         GO TO 150

      ENDIF



C
C     FROM HIGH STIFFNESS TO LOW STIFFNESS
C
      FP=F2
      FCP=F2C

      F2=U2 * PSTIFF
      F2C=V2*C2
      AP=A1+DA2
      EI=EI+(GA1+A1 + GA2+AP)*XMASS*DGU/2.0


      A2=(P2-F2C-F2)/XMASS
C     ACOR=(FP+FCP-F2C-F2)/XMASS
      ET=ET+(F1+FP)*DU/2.D0
      ED=ED+(F1C+FCP)*DU/2.D0

      RU=0.D0
      DU=0.D0
      DGU=0.D0
      GO TO 150
C
140   A2=A1+DA2
```

```
      IF(KODY.EQ.0.D0.AND.KODP.EQ.0.D0) RU=RU+DU
C
150   CALL ENERGY(XMASS,ST,C,DU,DGU,DT,PSTIFF,STIFF)
C
C     PROCEED TO OUTPUT
C
      IF (KPR.NE.10) GO TO 155
      WRITE(6,2070) T2,KK,EI,EK,ED,ES,EH,UB,UR,GA2,GV2
      WRITE(7,3068) T2,U2,V2,A2,F2,EI,EK,ED,ES,EH,EKS
      WRITE(11,3068) T2,U2
      WRITE(15,3068) T2,EI
      WRITE(17,3068) T2,ED
      WRITE(2,3068) T2,EKS
      WRITE(18,3068) T2,EKT
      KPR=0

C  Calculate maximum value
      IF (U2.GT.DISMAX) THEN
        DISMAX=U2
        TDIMAX=T2
      ENDIF
      IF (U2.LT.DISMIN) THEN
        DISMIN=U2
        TDIMIN=T2
      ENDIF

      IF (ED.GT.EDMAX) THEN
        EDMAX=ED
        TEDMAX=T2
      ENDIF

      IF (EI.GT.EIMAX) THEN
        EIMAX=EI
        TEIMAX=T2
      ENDIF

      IF (EKS.GT.EKSMAX) THEN
        EKSMAX=EKS
        TESMAX=T2
      ENDIF

      IF (EKT.GT.EKTMAX) THEN
        EKTMAX=EKT
        TETMAX=T2
      ENDIF

C
C     UPDATING INTEGRATION TIME STEP AND STRUCTURAL
C     RESPONSE QUANTITIES FOR THE NEXT TIME STEP
C
155   F1=F2
      F1C=F2C
      BS2=F2+F2C
      BS1=BS2
      P1=P2
      T1=T2
      A1=A2
      V1=V2
      U1=U2
      GA1=GA2
      GV1=GV2
      TO(KK)=T2
      UU(KK)=U2
      VV(KK)=V2
      AA(KK)=A2
      RR(KK)=F2
```

```
      CC(KK)=F2C
      BB(KK)=BS2
      GV(KK)=GV2
      SS(KK)=SG
      KD(KK)=KODY
      DT=DELTAT
      DTT=TT(II+1)-T1
      IF (DTT.EQ.0.D0) GO TO 160
      IF (DT.GT.DTT) DT=DTT
160   T2=T1+DT
      KODP=KODY
      KK=KK+1
      GO TO 20
C
C     PRINT RESPONSE TIME HISTORY AND SUMMARIES
C
400   WRITE(6,2090)
      WRITE(6,2095) (TO(I),UU(I),VV(I),AA(I),RR(I),I=1,KK,10)
      WRITE(6,2100)
      WRITE(6,2105) (TO(I),BB(I),GV(I),SS(I),KD(I),I=1,KK,10)
C

400   WRITE (20,3068) TBSMAX,BSMAX
      WRITE (20,3068) TBSMIN,BSMIN
      WRITE (20,3068) TDIMAX,DISMAX
      WRITE (20,3068) TDIMIN,DISMIN
      WRITE (20,3068) TEDMAX,EDMAX
      WRITE (20,3068) TEIMAX,EIMAX
      WRITE (20,3068) TESMAX,EKSMAX
      WRITE (20,3068) TETMAX,EKTMAX

2000  FORMAT(1H ,52(1H-),/,
     1      53H DYNAMIC RESPONSE OF SINGLE DEGREE OF FREEDOM SYSTEMS,/,
     2       1H ,52(1H-),//,1H ,8A10)
2005  FORMAT(19H SYSTEM DESCRIPTION,/,1H ,42(1H-),/,
     1       29H  MASS ..................... ,E14.6,/,
     2       29H  STIFFNESS ................ ,E14.6,/,
     3       29H  STRAIN HARDENING RATIO ... ,E14.6,/,
     4       29H  NATURAL FREQUENCY ........ ,E14.6,/,
     5       29H  PERIOD ................... ,E14.6,/,
     6       29H  DAMPING .................. ,E14.6,/,
     7       29H  SHIFT NATURAL FREQUENCY... ,E14.6,/,
     8       29H  SHIFT PERIOD.............. ,E14.6,/,
     9       29H  SHIFT DAMPING ............ ,E14.6)
2020  FORMAT(24H SOLUTION SPECIFICATIONS,/,1H ,42(1H-),/,
     1       29H  ANALYSIS TIME STEP ....... ,E14.6,/,
     2       29H    OUTPUT TIME STEP ....... ,E14.6,/)
2030  FORMAT(1H ,15(1H-),/,16H LOADING HISTORY,/,1H ,15(1H-),//,
     1      15H LOAD FACTOR = ,E14.6)
2035  FORMAT(//,4(10X,4HTIME,2X,12HACCELERATION))
2045  FORMAT(4(5X,F9.4,2X,E12.5))
2055  FORMAT(1H ,8A10)
2060  FORMAT(' ENERGY TIME HISTORY'/,
     1       '   TIME    STEPS       INPUT     KINETIC     DAMPING   ',
     2       '   STRAIN      HYSTE.     UNBAL.  EQUILIBRIUM     ',
     3       'GROUND       GROUND        GROUND'/,
     4       '              NO.        ENERGY      ENERGY      ENERGY   ',
     5       '   ENERGY      ENERGY     ENERGY     RATIO      ',
     6       'ACCELERATION   VELOCITY   DISPLACEMENT'/,1X,140(1H-))
2068  FORMAT(' OUTPUT TIME HISTORIES IN THE ORDER? TIME,',
     1       'DISPLACEMENT, VELOCITY, ACCELERATION, RESISTANCE,',
     2       'INPUT ENERGY,'/,' KINETIC ENERGY, HYSTERETIC ENERGY,',
     3       'DAMPING ENERGY, HYSTERETIC ENERGY DUCTILITY,',
     4       'RESIDUAL DUCTILITY.,'//)
2070  FORMAT(F8.4,I7,6F12.4,F12.6,3F13.4)
3068  FORMAT(F8.4,11F12.5)
```

```
2090  FORMAT(' RESPONSE TIME HISTORY'/,
     1        '      TIME        DISPLACEMENT       VELOCITY       ',
     2        'ACCELERATION      RESISTANCE'/,1X,78(1H-))
2095  FORMAT(F9.5,5X,F12.4,5X,F12.4,5X,F12.4,5X,F12.4)
2100  FORMAT(' BASE-SHEAR TIME HISTORY'/,
     1        '      TIME         BASE-SHEAR    GROUND-VELOCITY    ',
     2        '     SIGN              KODY'/,1X,77(1H-))
2105  FORMAT(F9.5,3F17.4,I14)
C



      RETURN
      END
C
      SUBROUTINE SOLVE(DT,DA,ST,C)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      CHARACTER*10 HED
      COMMON /BLK1/ XMASS,STIFF,PSTIFF,FACTOR,C1,C2,HED
      COMMON /BLK3/ DELTAT,P1,P2,DP,U1,U2,F1,F2,T1,T2,V1,V2,A1,A2
      COMMON /BLK8/ RU,F1C,F2C
C
      EFMAS=XMASS+C*DT/2.D0+ST*DT*DT/4.D0
      EFLOD=(DP-C*A1-ST*(V1+A1*DT/2.D0))*DT
      DA=EFLOD/EFMAS
      DV=A1*DT+DA*DT/2.D0
      DU=V1*DT+A1*DT*DT/2.D0+DA*DT*DT/4.D0
C
      VV=V1+DV
      RR=F1+ST*DU
      AA=(P1+DP*DT-C*VV-RR)/XMASS
      DA=AA-A1
C
      RETURN
      END
C
      SUBROUTINE BASE(BS,ST,C,DA,DT,DU)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      CHARACTER*10 HED
      COMMON /BLK1/ XMASS,STIFF,PSTIFF,FACTOR,C1,C2,HED
      COMMON /BLK3/ DELTAT,P1,P2,DP,U1,U2,F1,F2,T1,T2,V1,V2,A1,A2
      COMMON /BLK8/ RU,F1C,F2C
C
      DV=A1*DT+DA*DT/2.D0
      DU=V1*DT+A1*DT*DT/2.D0+DA*DT*DT/4.D0
      F2=F1+ST*DU
      F2C=F1C+C*DV
      BS=F2+F2C

C
      RETURN
      END
C
      SUBROUTINE ENERGY(XMASS,ST,C,DU,DGU,DT,PSTIFF,STIFF)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      COMMON /BLK2/ DAMP1,DOUT,PK,DAMP2,KOUNT
      COMMON /BLK3/ DELTAT,P1,P2,DP,U1,U2,F1,F2,T1,T2,V1,V2,A1,A2
      COMMON /BLK8/ RU,F1C,F2C
      COMMON /BLK4/ GA1,GA2,GV1,GV2,EI,ES,EH,ED,EK,ET,UB,UR,EKS,EKT

C
C     COMPUTE TIME HISTORY OF ENERGY INPUT, STORED , AND DISSIPATED
C     BY SINGLE DEGREE OF FREEDOM SYSTEM WITH STRAIN HARDENING
C
C     RECOVERABLE STRAIN ENERGY (ES), HYSTERETIC ENERGY (EH), DAMPING
C     ENERGY (ED) AND KINETIC ENERGY (EK)
```

```
C
      AT1=A1+GA1
      AT2=A2+GA2
      EI=EI+(AT1+AT2)*XMASS*DGU/2.0

      ED=ED+(F1C+F2C)*DU/2.D0
      ET=ET+(F1+F2)*DU/2.D0
      ES=0.5*PSTIFF*U2*U2 + 0.5*(STIFF-PSTIFF)*RU*RU
      EH=ET-ES
      VT=GV2+V2
      EK=0.5D0*XMASS*VT*VT
      EKS=ES+EK
      EKT=ET+EK
C
C     COMPUTE ENERGY OUT-OF-BALANCE RATIO
C
      UB=EI-ES-EH-ED-EK
      UR=UB/EI

      WRITE(*,1000) T2,EI,EK,ED,ES,EH,UB,UR
1000  FORMAT(10F12.5)
C
      RETURN
      END
C
      SUBROUTINE STATE(KODY,KODP,ST,C,SQ)
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      CHARACTER*10 HED
      COMMON /BLK1/ XMASS,STIFF,PSTIFF,FACTOR,C1,C2,HED

      COMMON /BLK3/ DELTAT,P1,P2,DP,U1,U2,F1,F2,T1,T2,V1,V2,A1,A2
      COMMON /BLK8/ RU,F1C,F2C
      COMMON /BLK4/ GA1,GA2,GV1,GV2,EI,ES,EH,ED,EK,ET,UB,UR,EKS,EKT
      COMMON /BLK7/ KPR
      COMMON /BLK9/ BSMAX,BSMIN,DISMAX,DISMIN,EDMAX,EIMAX,
     1              EKSMAX,EKTMAX
      COMMON /TIME/ TBSMAX,TBSMIN,TDIMAX,TDIMIN,TEDMAX,TEIMAX,
     1              TESMAX,TETMAX
C
      TEMP1=F1+F1C
      TEMP2=F2+F2C
      SP=TEMP1*V1
      SQ=TEMP2*V2
C
      IF (SP) 10,100,200
10    IF (SQ) 20,30,40
20    KODY=1
      ST=PSTIFF
      C=C2
      GO TO 400
30    KODY=0
      ST=STIFF
      C=C1
      IF (TEMP2.EQ.0.D0.AND.V2.EQ.0.D0) THEN
        KODY=1
        ST=PSTIFF
        C=C2
      ENDIF
      GO TO 400
40    KODY=0
      ST=STIFF
      C=C1
      GO TO 400
C
100   IF (SQ) 120,130,140
120   KODY=1
```

```
      ST=PSTIFF
      C=C2
      GO TO 400
130   KODY=0
      ST=STIFF
      C=C1
      IF (TEMP1.GE.0.D0.AND.TEMP2.GE.0.D0.AND.V1.GE.0.D0.AND.V2.GE.
     +  0.D0) THEN
             KODY=1
             ST=PSTIFF
             C=C2
      ENDIF
      IF (TEMP1.LE.0.D0.AND.TEMP2.LE.0.D0.AND.V1.LE.0.D0.AND.V2.LE.
     +  0.D0) THEN
             KODY=1
             ST=PSTIFF
             C=C2
      ENDIF
      GO TO 400
140   KODY=0
      ST=STIFF
      C=C1
      GO TO 400
C
200   IF (SQ) 220,230,240
220   KODY=1
      ST=PSTIFF
      C=C2
      GO TO 400
230   KODY=1
      ST=PSTIFF
      C=C2
      IF (TEMP1.GE.0.D0.AND.TEMP2.EQ.0.D0.AND.V1.GE.0.D0.AND.V2.EQ.
     +  0.D0) THEN
             KODY=0
             ST=STIFF
             C=C1
      ENDIF
      IF (TEMP1.LE.0.D0.AND.TEMP2.EQ.0.D0.AND.V1.LE.0.D0.AND.V2.EQ.
     +  0.D0) THEN
             KODY=0
             ST=STIFF
             C=C1
      ENDIF
      GO TO 400
240   KODY=0
      ST=STIFF
      C=C1
C
400   KPR=KPR+1
      IF (KPR.NE.10) GO TO 700
      KKKK=1
      IF (KODY.EQ.1) KKKK=-1
      WRITE(12,750) T2,TEMP2
      WRITE(13,750) T2,GV2
      WRITE(14,600) T2,KKKK

      IF (TEMP2.GT.BSMAX) THEN
        BSMAX=TEMP2
        TBSMAX=T2
      ENDIF
      IF (TEMP2.LT.BSMIN) THEN
        BSMIN=TEMP2
        TBSMIN=T2
      ENDIF
```

```
600   FORMAT(F15.3,I5)
700   WRITE(10,750) T2,F1,GV1,F2,GV2,KODP,KODY
750   FORMAT(5F15.3,2I5)
C
      RETURN
      END
```