Table 7.1 Summary of the penalty parameter settings applied to fish shoal optimization algorithm

Optimization Algorithm	**Type of riprap stones involved (ϕ)**	**Value of constant 'a' in Eq. 7.21**			**Remark**
		$j = 1$	$j = 2$	$j = 3$	
Fish Shoal Optimization	All types (31.8 ^{o}, 34.6 ^{o}, and 38.4 ^{o})	0.960	0.197	0.000	Parameter Setting 1
		0.960	0.722	0.052	Parameter Setting 2

Table 7.2 Range of decision variables adopted for the optimization algorithm

S. No.	**Angle of repose, ϕ(^{o})**	**Bottom width of canal, b (m)**	**Depth of flow, y (m)**	**Canal side slope, m_1(H): 1(V)**	**Canal side slope, m_2(H): 1(V)**	**Size of riprap stone, D (m)**
1	31.8	2.5-15.0	0.5-5.0	1.613-3.0	1.613-3.0	0.1-1.0
2	34.6	2.5-15.0	0.5-5.0	1.450-3.0	1.45-3.0	0.1-1.0
3	38.4	2.5-15.0	0.5-5.0	1.262-3.0	1.262-3.0	0.1-1.0

Table 7.3 Least cost canal characteristics obtained by application of FSO with two different sets of parameter settings

Freeboard scenarios	Angle of repose ϕ	Canal bottom width b	Flow depth y	Freeboard f	Side slope, z_1	Side slope, z_2	Riprap stone size, D	Top width T	Side slope perimeter P_s	Excavated area A_t	Discharge Q	Velocity V	Froude Number, Fr	Cost of construction $/m	Residual *LHS of Eq. 3.47*	Residual *LHS of Eq. 3.48*	Residual $R_1+R_2+R_3$	Basis of Selection
	Application of Fish Shoal Optimization algorithm involving all three types of riprap stones: Parameter Setting 1																	
k=0 C=0 x=0	38.4	5.6373	3.4338	0.0000	1.4812	1.4812	0.1029	15.8095	12.2735	36.8223	59.9998	1.6294	0.2808	253.6108	0.0000	0.0000	0.0000	GM
	38.4	5.6373	3.4338	0.0000	1.4812	1.4812	0.1029	15.8095	12.2735	36.8223	59.9998	1.6294	0.2808	253.6108	0.0000	0.0000	0.0000	MR
k=0.5 C=0 x=0	38.4	7.9273	2.9795	0.5000	1.4398	1.4398	0.1038	17.9465	12.1988	45.0136	59.9842	1.6479	0.3049	293.0299	0.0009	0.0007	0.0003	GM
	38.4	7.9272	2.9795	0.5000	1.4398	1.4397	0.1038	17.9463	12.1988	45.0131	59.9836	1.6479	0.3049	293.0276	0.0008	0.0003	0.0003	MR
k=0 C=0.5 x=0.25	38.4	6.1661	3.3250	0.6752	1.4520	1.4520	0.1082	17.7825	14.1048	47.8990	59.9947	1.6412	0.2874	316.4514	0.0112	0.0155	0.0011	GM
	38.4	6.1664	3.3267	0.6753	1.4520	1.4521	0.1081	17.7883	14.1113	47.9324	60.0462	1.6414	0.2874	316.6214	-0.0034	0.0033	0.0010	MR
k=0.25 C=0.25 x=0.25	38.4	5.7364	3.4304	0.5902	1.4444	1.4445	0.1121	17.3516	14.1270	46.4137	59.9989	1.6359	0.2821	311.9443	-0.0052	-0.0001	0.0002	GM
	38.4	5.7364	3.4304	0.5902	1.4444	1.4445	0.1121	17.3516	14.1270	46.4137	59.9989	1.6359	0.2821	311.9443	-0.0052	-0.0001	0.0002	MR
k=0.25 C=0.25 x=0.5	38.4	6.1661	3.3250	0.7059	1.4520	1.4520	0.1082	17.8716	14.2130	48.4460	59.9947	1.6412	0.2874	319.4724	0.0112	0.0155	0.0011	GM
	38.4	6.1664	3.3267	0.7060	1.4520	1.4521	0.1081	17.8775	14.2196	48.4802	60.0462	1.6414	0.2874	319.6460	-0.0034	0.0033	0.0010	MR
	Application of Fish Shoal Optimization algorithm involving all three types of riprap stones: Parameter Setting 2																	
k=0 C=0 x=0	34.6	8.2612	2.8965	0.0000	1.6254	1.6254	0.1217	17.6768	11.0550	37.5646	59.9999	1.5972	0.2997	276.2689	0.0000	0.0000	0.0000	GM
	34.6	8.2611	2.8965	0.0000	1.6254	1.6254	0.1217	17.6768	11.0550	37.5646	59.9999	1.5972	0.2997	276.2689	0.0000	0.0000	0.0000	MR
k=0.5 C=0 x=0	38.4	6.3899	3.2746	0.5000	1.4532	1.4532	0.1068	17.3606	13.3172	44.8249	59.9999	1.6435	0.2900	297.9471	0.0000	0.0000	0.0000	GM
	38.4	6.3899	3.2746	0.5000	1.4532	1.4532	0.1068	17.3606	13.3172	44.8249	59.9999	1.6435	0.2900	297.9471	0.0000	0.0000	0.0000	MR
k=0 C=0.5 x=0.25	38.4	7.9216	2.9857	0.6572	1.4276	1.4271	0.1076	18.3210	12.6977	47.7996	60.0014	1.6495	0.3048	310.0780	0.0010	-0.0366	0.0015	GM
	38.4	7.9216	2.9857	0.6572	1.4276	1.4271	0.1076	18.3210	12.6977	47.7996	60.0014	1.6495	0.3048	310.0780	0.0010	-0.0366	0.0015	MR
k=0.25 C=0.25 x=0.25	38.4	7.7918	3.0085	0.5793	1.4278	1.4269	0.1082	18.0337	12.5053	46.3274	59.9975	1.6501	0.3038	302.6389	0.0006	-0.0648	0.0026	GM
	38.4	7.7918	3.0085	0.5793	1.4278	1.4269	0.1082	18.0337	12.5053	46.3274	59.9975	1.6501	0.3038	302.6389	0.0006	-0.0648	0.0026	MR
k=0.25 C=0.25 x=0.5	38.4	7.9128	2.9871	0.6821	1.4277	1.4274	0.1076	18.3887	12.7905	48.2518	59.9990	1.6495	0.3048	312.5735	0.0008	-0.0209	0.0009	GM
	38.4	7.9128	2.9871	0.6821	1.4277	1.4274	0.1076	18.3887	12.7905	48.2518	59.9990	1.6495	0.3048	312.5735	0.0008	-0.0209	0.0009	MR

GM: Selection based on global minimum cost; MR: Selection based on minimum of sum of all the residuals