Indian Institute of Engineering Science and Technology, Shibpur

M. E. (Civil) 2nd Semester Final Examination, May 2014

Full Marks: 70 **Time 3 hours**

Subject: Probabilistic Design of Structures (CE 1026)

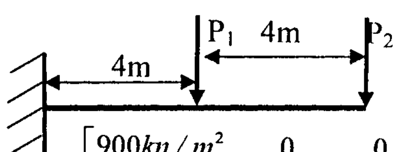
*Answer any **Five** Questions. All questions are of equal value. Assume any data reasonably, if required. All the notations used have their usual meanings.*

1A simply supported RC beam of span 8m is subjected to deterministic dead load of intensity 3 kN/m, random live load of mean intensity 6 kN/m and standard deviation of 3 kN/m. The allowable mean strength of concrete is 30.28 N/mm and SD=4.54. The allowable mean strength of steel is 320 N/mm and SD=32. Assuming all the random variables as normally distributed, obtain the reliability index by FOSM. The resistance of the beam can be taken as: $R = f_y A_{st} d\left[1 - \frac{0.77 f_y A_{st}}{bdf_{ck}}\right]$ Given, d=450m,b=250mm and Ast=1400 mm^2

2. A simply supported steel I beam subjected to a concentrated load P at centre. The thickness of web t_w = 1.25mm. The allowable shear stress is R and the depth of section is d and these are uncorrelated normal random variables with following given data: Load, expected value, μ_P = 4000 N, standard deviation, σ_P = 1000 N, allowable mean stress, μ_R = 95 N/mm^2, standard deviation, σ_R = 10 N/mm^2 The mean depth of section, μ_d =50 mm, standard deviation, σ_d =2.5 mm. Find the reliability index by FORM

3. A tension member is subjected to an axial load, P. The allowable tensile stress is R and the diameter of the circular cross section is d. All these parameters are uncorrelated normal random variables with following given data: μ_P = 5000 N, σ_P = 2000 N, μ_R = 280 N/mm^2, σ_R = 28 N/mm^2 and μ_d = 6 mm, σ_d = 0.6 mm. It is further given that the nominal value of load is 5200 N and nominal value of allowable stress 250 N/mm^2 and nominal value of diameter =5.5 mm. Then find the partial safety factors. Target reliability index =4.0

4. The cantilever beam is subjected to two concentrated load as shown in figure. The moment carrying capacity of the beam is M. P_1 and P_2 are correlated normal random variables with following given data:



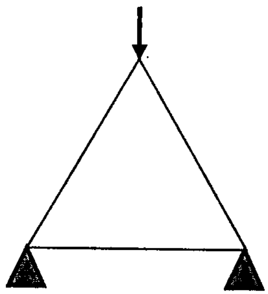
$$Mean:[\mu_M \quad \mu_{P1} \quad \mu_{P2}] = [250kN-m \quad 10kN \quad 10kN] \quad Cov: \begin{bmatrix} 900kn/m^2 & 0 & 0 \\ 0 & 9kN^2 & 6kN^2 \\ 0 & 6kN^2 & 9kN^2 \end{bmatrix}$$

Obtain the value of reliability index and also compare with reliability index when random variables are uncorrelated.

Also explain the steps of FORM algorithm for non-linear limit state equation involving correlated random variables.

5. How can you compute reliability of series system assuming independent events? Compute the system reliability of the truss shown in Fig Q (all members are of equal length) with following given data assuming all random variables are uncorrelated Gaussian:

$\mu_P = 25kN$, $\sigma_P = 10.0kN$, $\mu_{R1} = 50kN$ $\sigma_{R1} = 10kN$ $\mu_{R2} = 50\,kN$, $\sigma_{R2} = 10\,kN$ $\mu_{R3} = 30\,kN$, $\sigma_{R3} = 5\,kN$



6. Obtain a type –I response surface model for σ_{ac} as a function of l/r by Saturated Design method.Given, $\sigma_{ac} = 0.6 f_y f_{cc} \Big/ \left[(f_{cc})^{1.4} + (f_y)^{1.4} \right]^{1/1.4}$, where $f_{cc} = \pi^2 E/(\lambda)^2$, $\lambda = l/r$. Take, f_y=250 MPa, E=200 GPa. Take mean value of l/r as 120 and co-efficient of variation as 5%. Check the accuracy of the model.

7. a) A tension member is subjected to a load of 100 kN. The yield stress is 250 MPa. Design the cross-sectional area of the member by i) Working stress method, ii) Limit state method, and iii) Reliability based design method with probability of failure 2%. Compare the results. Given, co-efficient of variations for load, area and yield strength uncertainty are 30%, 5% and 10%, respectively.

b) Write down the design matrix for design of experiment with 2^k Factorial design with two standard normal variables with type IV polynomial.

8. A simply supported steel beam of length 6 m is subjected to uniformly distributed load w (normally distributed with mean 40 kN/m, standard deviation 10 kN/m). The moment carrying capacity of the beam is M_R (normally distributed with mean 250 kN-m and standard deviation 25 kN-m). Using direct Monte Carlo Simulation with five simulations calculate mean and standard deviation values of the bending moment and the probability of failure of the beam. Also, calculate CDF of bending moment. Given, u_i={0.594304, 0.842591, 0.71462, 0.052436, 0.194339, 0.472719, 0.797536, 0.532266, 0.479577, 0.994275}.

Standardized normal distribution function: a table of

$$F_U(u) = \frac{1}{(2\pi)^{1/2}} \int_{-\infty}^{u} e^{-x^2/2}\,dx,$$

for $u = 0.0$ to 3.69

u	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5733
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9482	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.8874	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3.0	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990
3.1	0.9990	0.9991	0.9991	0.9991	0.9992	0.9992	0.9992	0.9992	0.9993	0.9993
3.2	0.9993	0.9993	0.9994	0.9994	0.9994	0.9994	0.9994	0.9995	0.9995	0.9995
3.3	0.9995	0.9995	0.9995	0.9996	0.9996	0.9996	0.9996	0.9996	0.9996	0.9997
3.4	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9998
3.6	0.9998	0.9998	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999	0.9999