



सत्यमेव जयते

GOVERNMENT OF MAHARASHTRA

REPORT
OF THE
COMMISSION OF INQUIRY

BYCULLA
FLYOVER BRIDGE
BOMBAY

1987

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R E P O R T
OF THE
COMMISSION OF INQUIRY APPOINTED
TO INQUIRE INTO THE COLLAPSE OF
TWO PRESTRESSED GIRDERS OF THE
FLYOVER BRIDGE UNDER CONSTRUCTION
NEAR GLORIA CHURCH, BYCULLA
BOMBAY

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PART I

INTRODUCTORY

(i) Scope of the Inquiry

1. The present Inquiry under the Commissions of Inquiry Act, 1952, is naturally confined to investigation into the facts and collection of material facts from the evidence adduced before me. It is well-known that in such inquiry there are no adversaries nor are legal rights determined. Facts are collected and findings given with the object of informing the Government for such action as they may think proper. There is no adjudication in regard to any point of controversy. In this inquiry, witnesses have been referred to with reference to the "parties" calling them. This has been done for the sake of convenience. In a sense, all the witnesses are Commission's witnesses.

2. One of the facts on which I am called upon to give finding is whether there was any negligence on the part of any of the Engineers concerned with the work. This has naturally introduced an element of "controversy" between the groups of Engineers. But there is no charge of negligence against anyone. My endeavour has been to find out as a matter of fact whether the evidence points to the negligence of any one or more Engineers.

3. I have framed rules of procedure which govern the proceedings before me.¹

(ii) Commencement of Work

4. Under section 61 of the Bombay Municipal Corporation Act, construction of bridges and roads is an obligation of the Municipal Corporation. In September 1980, the Byculla Flyover Bridge was under construction. The site of the bridge is near Gloria Church, Byculla. The bridge was proposed to be made up of four prestressed girders on the northern side and four similar girders on the southern side. This inquiry is concerned with two girders on the northern side. The dimensions of each girder were as follows :

| | | | | |
|----------------------------|----|----|----|--------------|
| Length | .. | .. | .. | 36.4 metres. |
| Width of the top flange | .. | .. | .. | 1.0 metre. |
| Width of the bottom flange | .. | .. | .. | 0.6 metre. |
| Weight | .. | .. | .. | 72.0 Tonnes. |

Two girders were under construction. The span between the girders was to consist of R.C.C. slabs. Around 2-30 a.m. on 30th September 1980, the two prestressed girders which were under construction near Gloria

¹ Appendix 'A'—Rules of Procedure.

Church suddenly collapsed. The Bombay Municipal Corporation by its Resolution No. 1018 dated 21st November 1980 requested the Government of Maharashtra to institute a judicial inquiry to investigate into certain matters connected with the collapse of the two girders. In view of the public importance of the matter, the Government of Maharashtra by its Notification No. BMC/2380/4289-UD-3, dated 28th January 1981 appointed me to hold judicial inquiry under the Commissions of Inquiry Act. The notification required me to investigate into these matters :—

- (i) Causes of the collapse of the two prestressed girders.
- (ii) Circumstances in which the collapse occurred.
- (iii) Whether adequate actions were taken by the authorities concerned to avoid or mitigate the consequences of the collapse.
- (iv) Determination of the responsibilities of the Officers, servants or Engineers of the Corporation and the Contractors.

5. Initially, I considered whether I should have Assessors to assist me. However, on going through the various documents produced by the Bombay Municipal Corporation, I thought that it was possible to hold the inquiry without Assessors. I did not, therefore, appoint any Engineer as Assessor to assist me in the inquiry.

6. The subject of the Inquiry demanded association of Specialists in Engineering. I, therefore, appointed Mr. Shirish Patel, Dr. V. N. Gupchup and Mr. R. G. Gandhi, Engineers of unquestioned distinction, to investigate the matter of the collapse of the girders and make a report. They commenced work soon after their appointment on 30th March 1981.

7. It was brought to my notice that an Assistant of Mr. Shirish Patel had prepared designs for a firm of Contractors who competed with Messrs. Model Construction Company in regard to the work of Byculla Flyover Bridge. Messrs. Model Construction Company were awarded the contract of construction of the bridge to which this inquiry relates. Mr. Patel did not know this fact. Immediately on knowing this fact, he graciously withdrew from the work assigned to him. The Panel of Experts which was until then composed of Mr. Shirish Patel, Dr. V. N. Gupchup and Mr. R. G. Gandhi was reconstituted in view of the exit of Mr. Shirish Patel. On my request Dr. Gupchup and Mr. Gandhi continued their association with the Panel. Dr. N. G. Bondre, Consulting Engineer was requested to take the place of Mr. Patel. He agreed. This was on 7th April 1981. The original Panel was formed on 30th March 1981. The reconstituted Panel had to start the work over again on 7th April 1981. The Panel submitted its report on 19th May 1981.

(iii) Staff of the Commission

8. I was assisted by an efficient Secretary. Mr. I. S. Mecwan showed initiative, dash and willingness to work and learn. I am thankful to him.

9. The Bombay Municipal Corporation readily placed at my disposal their staff.²

In addition, I appointed Mr. M. L. Saxena, a retired Secretary to the Chief Justice of the High Court as my Personal Assistant.

10. On 6th February 1981, the Principal Judge, Bombay City Civil Court, on my request, recommended to the High Court that the members of the Court staff be deputed to work on the establishment of the Commission. Their Lordships of the High Court provisionally permitted the Principal Judge to place the services of the staff at the disposal of the Commission.³

(iv) Public Notification

11. Immediately on the appointment of the staff, a notification inviting information from members of the public was issued. The notification was published on 2nd March 1981 in the English Dailies "Times of India" and "Indian Express", the Gujarati Dailies "Janmabhumi" and "Mumbai Samachar", the Hindi Daily "Navbharat Times", the Marathi Dailies "Maharashtra Times" and "Loksatta" and the Urdu Daily "Inquilab".⁴

12. Meanwhile on 5th March 1981, on my request the Bombay Municipal Corporation produced all the relevant documents and files connected with the Bridge.

(v) Affidavit

13. Only one member of the Public made an affidavit in response to the notification issued by me. It was Mr. Gauranga Chowdhari, an Engineer who was in charge of the Flyover Bridge at Wadala. In his affidavit he has narrated his experience of the collapse of one girder of the Flyover at Wadala. The Municipal Corporation of Greater Bombay filed affidavits of the following Officers :

- (i) Mr. V. S. Nawathe, Deputy City Engineer (Project),
- (ii) Mr. S. K. Umadi, Executive Engineer,
- (iii) Mr. J. N. Sanghadia, Assistant Engineer,
- (iv) Mr. K. M. Desai, Sub-Engineer,
- (v) Mr. Y. V. Palshetkar, Junior Engineer,
- (vi) Mr. N. M. Dhanawade, Mukadam,
- (vii) Mr. C. G. Dalvi, Mukadam.

Messrs. Model Construction Company who had taken the contract from the Bombay Municipal Corporation filed affidavits of :

- (i) Mr. M. S. Diwan, Consulting Engineer of Model Construction Company.

² Appendix 'B'—List of Members of Staff.

³ Appendix 'B'—List of Members of Staff.

⁴ Appendix 'C'—Copy of the Public Notification.

- (ii) Mr. G. D. Joshi, Partner of Model Construction Company.
- (iii) Mr. G. V. Paranjape, Site Engineer of Model Construction Company.

These are all the affidavits received by me.

(vi) Panel of Experts

14. Dr. V. N. Gupchup, Vice-Principal, V.J.T.I., Matunga, Bombay, is distinguished in the field of structural engineering. A Doctor of Science in Civil Engineering, Massachusetts Institute of Technology, U.S.A. and a Master of Science of Civil Engineering from the same institute, Dr. Gupchup possesses professional experience of varied dimensions. The important design projects handled by him include—

(i) Member of the group of Engineers in Bechtel Corporation to study the Dynamic Response of Overhead Structures, subjected to loading of moving vehicles and also to seismic forces for the Bay Area Rapid Transit System. San Francisco, U.S.A. (1963-64).

(ii) Organisation of soils investigation for Madras Refinery Project, India, for Engineers India Ltd. (1965).

(iii) Consulting Engineer for the design of reinforced concrete structures for the campus of the Jiwaji University, Gwalior, India (1966-67).

(iv) Consultant to Messrs. Hindustan Construction Company, Bombay, India, to study the possible effects of blasting operations in the quarry in the vicinity of the proposed site for the construction of Idikki Arch Dam in Kerala State, India (1966).

(v) Consulting Engineer for the design of reinforced concrete and steel structures for the office and factory of Kirloskar Pneumatic Company, Poona, India (1967-68).

(vi) Consulting Engineer for the design of reinforced concrete and steel structures, including buildings, water tanks and storage silos of the Silicon Carbide Plant for Grindwell Norton Ltd., Bangalore, India (1971-72) and (1976-77) (work in progress).

(vii) Consulting Structural Engineer for the proposed "Development of the Ajanta Hills Area"—Project undertaken by the Maharashtra Tourism Development Corporation (1967-77 work in progress).

The Research projects handled by him include—

(i) Co-Investigator for the project involving study of "Effects of Re-Vibration on the properties for concrete", sponsored by Council of Scientific and Industrial Research, Government of India, New Delhi (1970-72).

(ii) Member of the group of Consulting Engineers appointed by the Department of Atomic Energy, Bombay, India, to investigate the dynamic behaviour of Nuclear Power Plants subjected to seismic effects (1971).

(iii) Principal Investigator for the project for developing computer programmes for the design of Crane Box Girders, sponsored by Western Mechanical Industries, Bombay, India (1972).

(iv) Principal Investigator for the project for studying the "Utility of Bamboo as reinforcement in concrete" sponsored by City and Industrial Development Corporation, Government of Maharashtra, India (1972-73).

(v) Principal Investigator for the project involving "The study of the use of fly ash (from the Thermal Power Station at Nashik) in concrete", sponsored by City and Industrial Development Corporation, Government of Maharashtra, India (1973-74).

(vi) Principal Investigator for the project involving a large-scale load test of Mahim Causeway bridge in Bombay during the passage of a special tractor trailer carrying the main reaction vessel of the Nuclear Power Plant at Kota, India,—project sponsored by Power Projects Engineering Division, Department of Atomic Energy, Bombay, India (1973).

(vii) Principal Investigator for the project for the study of "Effect of reduction in bearing area at splice joints in columns"—project sponsored by Power Projects Engineering Division, Department of Atomic Energy, Government of India (1976-77).

Mr. R. G. Gandhi, who is currently the Chairman of (i) Acrow India Limited, (ii) Vikhroli Metal Fabricators Limited, Bombay, (iii) Ganga Bridge Construction Company Limited and other Corporations is endowed with rich experience in the construction of roads and bridges. Mr. Gandhi possesses vast experience. I will cite a few examples of the projects which he has handled. The Idikki Power Project in Kerala, Yamuna Hydro Electric Project with underground Power Station in Himalayas, Sharavati Valley Power Project, Karnataka and several other projects. Mr. Gandhi has mature experience acquired from participation in so many important projects.

Dr. N. G. Bondre is as distinguished an Engineer as Dr. Gupchup and Mr. Gandhi. He holds B.Sc. (Civil Engineering) degree from London University and Ph.D. degree from the same University. Between 1955 and 1957 he worked as Senior Technical Assistant with the Port of London Authority. The work consisted of concrete mix design, quality control of site concrete. Between 1958 and 1960 he was a Design Engineer with a construction company at New Delhi. In such capacity he designed various prestressed concrete bridges. In 1960-61 he was a partner of a firm known as Messrs. H. Moller and Company, New Delhi. During these years, he handled the designs of prestressed concrete bridges and construction equipment such as launching girders and so on. Since 1961 to this date he has been practising as a Consulting Structural Engineer in Bombay. He has handled the design of Oberoi Sheraton and NPK Fertilizer Plant at Kandla.⁵

⁵ Appendix 'D'—Statements of Qualifications and Experience of Dr. Gupchup, Dr. Bondre, Mr. Gandhi and Mr. Gajapathy Rao.

15. Dr. Gupchup combines in him the experience in the academic field of teaching up to post-graduate and Doctorate levels and practical experience as Consulting Engineer. Mr. Gandhi with his vast experience as General Manager of Hindustan Construction Limited and the various assignments undertaken, introduced into his work practical experience of the Site Engineers. Dr. Bondre with his experience as Consulting Engineer particularly in the work of designing of bridges, was a great asset to me. The members of the Panel represented the three different branches of profession of Engineering—the Academic-cum-Consulting Engineer, Construction Engineer and the Practising Consultant. The composition of the Panel was broad based. Each member of the Panel is talented and possesses expertise required for this work. I am satisfied that I was aided in my work with the report of a Panel consisting of such learned men.

(vii) Mr. M. P. Gajapathy Rao⁶

16. Mr. Gajapathy Rao is currently Executive Engineer, Police Housing Corporation, a Corporation owned by the Government of Maharashtra. I entrusted to him under section 5-A of the Commissions of Inquiry Act, the work of making report similar to that made by the Panel of Experts. His experience as Research Assistant, Central Water and Power Research Station, Pune, then Executive Engineer and Superintending Engineer in various projects especially the field of designs, introduced in his work the requisite expertise. Mr. Gajapathy Rao has impressed on his report the stamp of his expertise in the matter of design and design calculations. I did not examine Mr. Gajapathy Rao as a witness. The Contractors and the Corporation did not have an opportunity of testing the report of Mr. Gajapathy Rao by cross-examination. I have, therefore, not relied upon his opinions in this Report.

(viii) Counsel

17. I decided to allow "parties" to appear through counsel. It was permissible to hold the inquiry without the aid of counsel. But as the events during this inquiry have proved, it was difficult to bring out all the facts without the assistance of counsel. The process of recording oral evidence and cross-examination of witnesses inevitably causes delays. But the purpose of judicial inquiry will be frustrated if elaborate oral evidence and meticulous cross-examination were not allowed. I was not oblivious to the delay-causing factors in the judicial process. I had indeed thought of an alternative procedure which would have terminated inquiry much earlier. The method was to investigate the case myself by questioning the persons concerned with this matter. This would have been a speedy inquiry. But a large number of facts would not have come to surface. The results were bound to be unsatisfactory. On the other hand elaborate oral evidence, scrutiny of each document, testing the opinion of experts by oral evidence takes more time. But the investigation is thorough, complete, broad based

⁶ Appendix 'D'—Statements of qualifications and experience of Dr. Gupchup, Dr. Bondre, Mr. Gandhi and Mr. Gajapathy Rao.

and fair. The latter process, no doubt, needs more time and effort. But its perfection cannot be doubted. On a balance of consideration of advantages and disadvantages of different methods of inquiry, I finally chose the traditional method of recording oral evidence about facts relevant to the inquiry.

18. I will be failing in my duty, if I do not mention the name of Mr. M. B. Rele, Counsel for the Commission. He has spent numerous days in reading the voluminous record produced by the Bombay Municipal Corporation. His cross-examination was penetrating and critical. It resulted in the discovery of a mass of facts, each of which is relevant to this inquiry. Mr. Rele conducted his cross-examination with industry, diligence and dignity.[†]

(ix) Codes

19. The Bombay Municipal Corporation, the Contractors and the Commission were represented by counsel in this inquiry. There are witnesses examined by these three "parties". They have produced documents. The following codes have been used in this inquiry to denote the documents exhibited and witnesses examined :

| | | | |
|--|----|----|--------------|
| Municipal Witnesses | .. | .. | M.W. |
| Contractors' Witnesses | .. | .. | Con. W. |
| Commission's Witnesses | .. | .. | C.W. |
| Documents of the Municipal Corporation | .. | .. | Ex. M. No. |
| Documents of the Contractors | .. | .. | Ex. Con. No. |
| Documents of the Commission | .. | .. | Ex. C. No. |

(x) Appendices

20. Documents exhibited as evidence in this inquiry are different from the Appendices. The Appendices to this report are mentioned below :

- (A) Rules of Procedure.
- (B) List of members of staff.
- (C) Copy of the Public Notification.
- (D) Statements of qualifications and experience of Dr. V. N. Gupchup, Dr. N. G. Bondre, Mr. R. G. Gandhi and Mr. M. P. Gajapathy Rao.
- (E) List of Counsel.
- (F) List of documents produced by the Corporation and exhibited in the proceedings.
- (G) List of documents produced by the Contractors and exhibited in the proceedings.
- (H) List of documents produced and exhibited by the Commission.
- (I) List of Drawings.

[†] Appendix 'E'—List of Counsel.

(xi) Visits to the Site

21. I visited the site of the collapse on four occasions. I first visited the site on 3rd March 1981 before the parties were represented by Counsel. The notes of the inspection made on these visits are on the record of this Inquiry.

(xii) A Word of Gratitude

22. I express my gratitude to the Government of Maharashtra, Mr. R. T. Atre, the Secretary, Public Works and Housing Department readily spared the services of Mr. M. P. Gajapathy Rao to assist me by making a report. Similarly, Mr. P. G. Salvi, Secretary, Home Department, was good enough to spare the services of the Assistant Commissioner of Police to investigate certain facts and report to me. The Bombay Municipal Corporation extended its ready and unflinching co-operation in every matter connected with the inquiry. Everything I asked them to do was done with extreme promptness and willingness. There was no red tape. No delay. Willingness to co-operate with me was sincere and spontaneous. I am particularly grateful to Mr. J. R. Patwardhan, Deputy Municipal Commissioner (Engineering) who took decisions with great care and speed. My staff did not lag behind. They worked willingly and with a smile. I wish to make a special reference to my Stenographers, Miss Vidya Bolar, Mr. R. M. Potnis and Mr. M. L. Saxena.

(xiii) Witnesses

23. The documents produced before me are listed in the Appendices. The Bombay Municipal Corporation examined Mr. V. S. Nawathe, Deputy City Engineer (Project) (M.W.-1), Mr. S. K. Umadi, Executive Engineer (M. W.-2), Mr. K. M. Desai, Sub-Engineer (M.W.-3), Mr. J. N. Sanghadia, Assistant Engineer (M.W.-4) and Mr. Y. V. Palshetkar, Junior Engineer (M.W.-5). Messrs. Model Construction Company led the evidence of Mr. M. S. Diwan, their Consulting Engineer (Con. W-1), Mr. G. V. Paranjape, their Site Engineer (Con. W-2) and Mr. G. D. Joshi, a Partner of Messrs. Model Construction Company (Con. W-3).

PART I—Concluded

PART II

THE PROJECT—CONSTRUCTION OF GIRDERS—COLLAPSE

(i) The Project

24. The administrative approval for the project of the Byculla Flyover Bridge was secured sometime in 1976. The project was prepared by the Planning Department of the Corporation. Eventually, the plans and estimates were prepared and submitted to the Works Committee of the Corporation. The Works Committee approved the project in February 1977. The estimated cost was Rs. 80,49,832.

25. Notice inviting the tenders for the Byculla Flyover Bridge was published on 28th October 1976. The last date was 15th December 1976. Messrs. Model Construction Company along with five others submitted tenders. The Standing Committee of the Municipal Corporation accepted the tender submitted by Messrs. Model Construction Company, Messrs. Model Construction Company is a firm consisting of the following partners :

- (1) Mr. Dattatraya B. Vedak.
- (2) Mr. Keshav D. Pendse.
- (3) Mr. Suhas S. Pethe.
- (4) Mr. D. R. Mahabaleshwarkar.
- (5) Mr. Govind Dhondo Joshi.
- (6) Mr. R. B. Naiksatam.

The designs submitted by them were examined. The work order was issued to Messrs. Model Construction Company, who were expected to start the work on 11th April 1977. The tenderers had an option of either acting on the plans prepared by the Corporation or submit their own plans. In the latter event they were required to engage a Consulting Engineer. Messrs. Model Construction Company chose the latter course. The Municipal Corporation, therefore, insisted upon the appointment of a Consulting Engineer for the contractors. Mr. M. S. Diwan, Consulting Engineer was appointed by the Contractors. His appointment was approved by the Corporation.

26. The Byculla Flyover Bridge was proposed to be built near the junction of Sant Sawta Marg and Dr. Babasaheb Ambedkar Road. Gloria Church is situated at this junction. The Flyover Bridge consisted of 4 R.C.C. spans, each on the North and South side, which joined the

bridge on the either side. Between them, four prestressed girders were to be erected. The dimensions of each girder were these :

| | | | |
|---|----|----|--------------|
| Width of the top flange | .. | .. | 1.0 metre. |
| Width of the bottom flange | .. | .. | 0.6 metre. |
| Length | .. | .. | 36.4 metres. |
| Height up to articulation | .. | .. | 1.0 metre. |
| Height above articulation | .. | .. | 0.95 metre |
| Distance between two Girders, centre to centre. | | | 2.2 metres. |

Drawings in respect of various stages of the construction were submitted by the contractors from time to time. All the drawings do not bear the stamp of approval by the Corporation. A number of them do not bear even drawing numbers. Nor do all bear dates. A classified list of the drawings is in Appendix 'H'. Among the drawings, the following are important for the purpose of considering the questions arising in this inquiry :

| | | |
|-----------|----|--|
| Ex. M-38A | .. | Plan showing location of 4 Prestressed Concrete Girders and the plan for lowering them. |
| Ex. M-38B | .. | Steel crib arrangement for supporting prestressed concrete girders at the ends until they are lowered to the final position on the portal columns. |
| Ex. M-38C | .. | Details of prestressed concrete girder for straight span. |
| Ex. M-38D | .. | Details of R.C.C. girder steel end block, Articulation Diaphragm etc. |
| Ex. M-38E | .. | Details of superstructure straight span. |
| Ex. M-38F | .. | General arrangement for form work for centering. |
| Ex. M-43 | .. | Cable Extension Chart. |

None of these drawings bear the stamp of approval. The only drawings on which considerable controversy has arisen are those contained in Ex. M-38 and M-43. The drawings of centering system are not generally sent for approval to the Planning Department because they relate to temporary structures. Such drawings are approved at the site in a joint meeting of the Engineers of the Corporation and the Contractors.

(ii) Delay in execution of work

27. The work was to commence on 11th April 1977, both at Byculla and Lalbaug. The Contractors allege that the land was not given to them in time and, therefore, there was delay in carrying out the work in accordance with the time schedule agreed upon. This complaint does not appear to be justified in view of the correspondence to which I will presently make a reference.

On 6th April 1977 (Ex. M-21, page 111) the contractors were requested to take up preliminary arrangements with the Executive Engineer and submit a programme of the work in accordance with clause 47 of the contract. There is no evidence that such a programme was submitted to the Municipal Corporation.

On 2nd November 1977, the Executive Engineer (Project I) wrote to the Contractors :

“Work like pile caps, column is not picking up the desired speed because the contractors had not engaged the adequate number of Labourers and Mukadams.”

On 6th January 1978 a similar complaint was made in writing by the Deputy City Engineer (Project)

On 18th October 1978 the Deputy City Engineer (Project) wrote to the contractors that no vigorous efforts were made by the latter to carry out the work.

The Deputy City Engineer (Project) visited the site on 22nd November 1978 and found that there was no activity of construction at all.

In the letter dated 27th December 1978 he complained about this fact and stated :

“The latest PERT-chart submitted by the contractors was vague and did not indicate the latest dates of commencement and completion of work.”

28. It is not necessary to repeat such references. Letters in the correspondence file No. 1 and Memoranda in the triplicate books (Ex. M-15, M-21 and M-22) reveal that the Corporation has been complaining about the lapses of the Contractors. Such complaints continued right up to the month of July 1980. It does not, therefore, appear that there was any delay on the part of the Municipal Corporation which should give cause to the Contractors to delay the completion of the work. None of these letters have been replied satisfactorily by the contractors.

29. The Junior Engineer by name Mr. Rajwade, who appears to have worked with diligence, placed on record certain account of work of the contractors. On 22nd April 1980 (Ex. M-15B) he brought to the notice of the contractor that the joint between the shuttering was not properly sealed and warned that unless this was done, no concreting will be allowed. On 6th June 1980 (Ex. M-15B, page 9) he expressed dissatisfaction at the quality of sand brought by the Contractors. Again on 6th August 1980, the Assistant Engineer recorded that the shuttering material was not up to the standard. On 2nd September 1980 (Ex. M-15C, pages 5-7) the contractors were told that the centering for slab No. 17 was defective inasmuch as the props were slender and bent. Props were not vertical. The contractors were warned that the concreting will not be allowed unless the defects were rectified. Another complaint was made on 21st September

1980 (Ex. M-15C, page 10) that numerous props were "jointed". Defects in the propping arrangement of slab No. 17 were brought to the notice of the contractor on 27th November 1978 (Ex. M-15C, pages 48-49) by Sub-Engineer, Mr. Nadkarni, who too was working conscientiously and carefully.

30. Finally, there is a letter dated 9th November 1978 (Ex. M-15C, page 30). This letter emphasizes that there was no full-time qualified engineer at the site at all. The poor quality of work was attributed by the Sub-Engineer to the absence of a qualified engineer at the site.

This is the general background about the quality of the supervision by the Corporation and the quality of work of the Contractors.

(iii) Engineers in charge of the work

31. In order to understand the quality of supervision, the cause of collapse and the responsibilities, it is necessary to set out in a nutshell the academic qualifications, experience and expertise of different engineers, who were concerned with the construction of the bridge.

(a) Mr. V. S. Nawathe

He has been in the employment of the Corporation for about 29 years. Presumably he joined as a Sub-Engineer. Around 1976-77 he was promoted as Deputy City Engineer. He is in charge of all Civil Engineering Works of the Corporation in the City of Bombay, except the works connected with buildings and sewerage. He is second in rank in the hierarchy of Engineers of the Corporation, the City Engineer being the first one. His work consists of overall supervision of all the projects of the Corporation. The Executive Engineer, who is immediately subordinate to him, is directly answerable to him. Mr. Nawathe is required to visit the site as often as he could, depending upon the exigencies of the work. He supervised the work of the Flyovers of the Corporation at Matunga and Wadala. But he does not possess any special qualification or experience in bridge engineering. Indeed, he admitted that he is not aware as to whether there exists any special qualification in bridge engineering. The evidence reveals that Bridge Engineering is a special subject for the post-graduate course and doctorate.

(b) Mr. Shankar Umadi

He has been the Executive Engineer in charge of the Byculla Flyover Bridge as also several other projects of the Corporation. He has been with the Byculla Flyover Project right since beginning in March 1977. He too does not possess any experience or qualification in Bridge Engineering. The only prestressed girder bridge supervised by him was the Bridge at Lalbaug, a part of the same project. He has no experience of prestressed concrete work. Nor did he come across work of prestressing until he was posted at the Lalbaug site.

(c) Mr. J. N. Sanghadia

A graduate in Engineering from Vallabh Vidyanagar University, Anand, he has been in the employment of the Corporation since 1964. He joined as a Sub-Engineer and was promoted as Assistant Engineer on 1st October 1974. On 5th July 1980 he was posted to work at the Byculla Flyover Bridge site upon the transfer of Mr. Matey. He has neither training nor experience of bridge building. Prestressing concrete is also a new subject for him. Erection of bridge, stressing of cables of the girders and the centering system of bridge are all new subjects to him.

(d) Mr. K. M. Desai

A graduate in Civil Engineering from Bombay University, he has been in the employment of the Corporation for about 14 years. Most of the work done by him was in connection with roads and bridges. His very first appointment on the bridge work was at Lalbaug Flyover site. He was posted at Byculla Flyover Bridge about a month before the bridge collapsed. He joined the site on 27th August 1980. As in the case of other Engineers of the Corporation, Mr. Desai too does not possess qualification in or experience of bridges. Similarly, he does not have any experience of the prestressing work or the work of centering of the bridges.

(e) Mr. Y. V. Palshetkar

He holds a Diploma in Civil Engineering from the Government. Since 1972 he is employed as Junior Engineer in the Corporation. Absolutely without experience of bridges or prestressing concrete, his very first experience of bridge was at Lalbaug, where he was posted in 1975. Naturally, he has no experience or knowledge of centering of bridges.

(f) Mr. M. S. Diwan, Consulting Engineer of the Contractors

Mr. Diwan is 52 years old. He graduated from the Pune Engineering College in 1948. He does not refer to any distinction in his examination. However, among the qualifications claimed by him are his selection by the Central Government Engineering Services in 1950, selection for the Indian Railway Services Engineers Class I and the passing of the Examination of Institute of Structural Engineers, London, in 1960. In the London Examination he secured Fourth rank and received Andrews Prize. He has written a book titled "Problems in Theory of Structures".

He does possess experience of bridges. He has experience of working at the site of Tasu Bridge at Vaitarna. The magnitude of the work or dimensions of this bridge have not been stated by him. He was the Assistant Engineer in the Raliways and was concerned with Sevalaya Bridge near Anand, Gujarat. He has also worked at the site of Ganga Bridge Project as Assistant Engineer. He was the Executive Engineer in charge of two prestressed railway bridges at Bhildi-Raniwara. All this experience was as an employee. In none of these works he claims to have been the leader of the Engineers working on the project.

He commenced his career as Consulting Engineer in 1975. Lalbaug Bridge project of the Contractors was the second project of his career as Consultant. All the drawings of Lalbaug as also the Byculla Flyover Bridge were prepared by him. Therefore, Mr. Diwan had been practising as Consulting Engineer for hardly two years before the assignment of the Flyover Bridges to the Contractors. His experience at the sites of various bridges enumerated by him was in a subordinate capacity. The experience of Mr. Diwan has to be borne in mind in evaluating his role in this bridge work. But the fact that he does not possess extensive experience as Consulting Engineer cannot be lost sight of in appreciating his role in the construction of the Flyover.

(g) Mr. G. D. Joshi

Mr. Joshi has a distinguished academic career. He stood first at the examination for the Diploma in Civil Engineering. Thereafter, he was admitted to the second year of the degree course. At the second year and the third year he topped the list of the Pune University students. He stood First and received the Gold Medal in the B.E. Examination for his performance in the paper on Structural Engineering. He was employed in the Municipal Corporation for a long time and ventured into an independent business after resigning his job. He is one of the Engineering Partners of the Contractors. The other Engineering Partner, Mr. Naiksatam was also an employee of the Corporation. Mr. Joshi has never worked on any bridge. He has no experience of prestressing work. On the whole, it appears that he is altogether inexperienced in building bridges and prestressed structures. He has made no secret of the fact that it was Mr. Diwan, who was his guide and the leader in this project.

(h) Mr. G. V. Paranjape

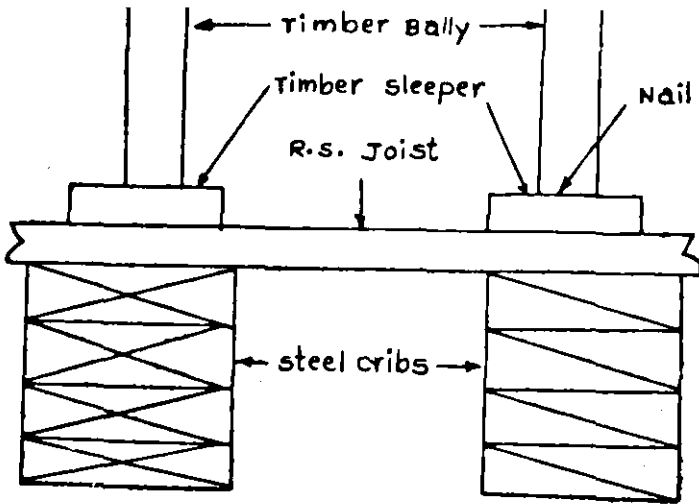
Mr. Paranjape passed B.E. (Civil) of the University of Bombay in 1977. In the same year he took up employment with the Contractors. Byculla Flyover Bridge was the first bridge project in his career. He was appointed at the Byculla Flyover Bridge from 1st January 1980. He does not speak of possession of distinction in any subject. It is reasonable to conclude that of all the Engineers at the site, Mr. Paranjape was the most inexperienced Engineer. As the Site Engineer of the Byculla Flyover Bridge Project he represented the Contractors. Naturally, every act of his was done on the instructions of Mr. Diwan and Mr. Joshi.

(iv) The Centering or Supporting System

32. The work of construction of the Lalbaug Bridge commenced in October 1977 and that of the Byculla Bridge on 11th April 1977. The design for centering of both the girders was conceived in August 1979. The Contractors did not own any steel cribs. They borrowed 100 steel cribs from another Contractor—Gopaldas Vasudeo. It is only after knowing about the availability of the cribs that Mr. Diwan prepared the drawings of centering system. Acrow pipes were also borrowed.

33. There is a single drawing or design for the centering system for all the four girders of the Byculla Flyover Bridge. It is Ex. M-38F. The centering of Girder No. 1 was of acrow pipes. The centering for Girder No. 2 was designed to be erected in this manner :

Four layers of steel cribs placed one over the other. Over them R.S. Joists of the dimension of 10"×5" were proposed to be kept. Timber sleepers of the dimensions of 150×100×1800 mm. were placed above the R.S. Joists. Over the timber sleepers, timber ballies of the cross section of 75 mm. were proposed to be placed at the distance of 450 mm. centre to centre. The steel cribs were placed in order to increase the height of the centering system. The height of ballies is not mentioned in Ex. M-38F. The horizontal bracings were proposed to be of bamboos placed at a distance of 600 cm. centre to centre. Diameter of each bamboo bracing was 25 mm. A rough sketch of the centering of Girder No. 2 would appear thus :



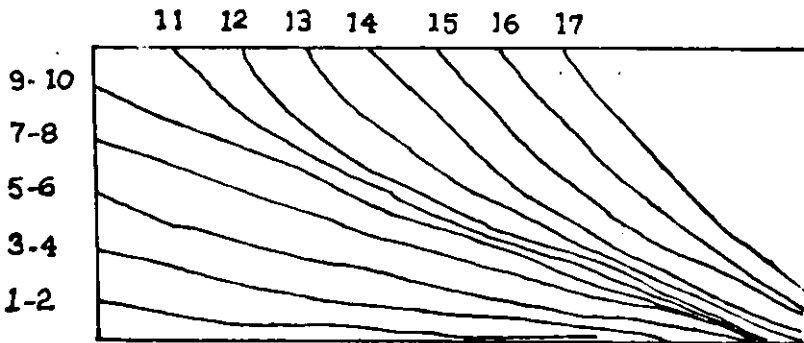
The Girder No. 1 was supported on the centering made up of acrow pipes. The Girder No. 2 was supported on the centering composed of steel cribs, R.S. Joists, timber sleepers and above them timber ballies, as in the above sketch. Ex. M-38F is the design for the centering of all the four girders at the Byculla bridge. Before the design was finalised, Mr. Diwan had discussions with the Contractors and the Engineers of the Corporation. During these discussions, Mr. Umadi (M.W.-2) suggested that the Contractors should own the requisite number of steel cribs. In February 1980 the Lalbaug bridge was complete. It is thereafter that the centering work of the Byculla bridge was taken up. The same design as was used for Lalbaug bridge was used for Byculla bridge with modifications to suit the

dimensions of the bridge. The design was submitted for approval in March 1980. It was approved at the site by Mr. Nawathe and Mr. Umadi on the one hand and Mr. Diwan and Mr. Joshi on the other.

Though the centering of the Girder Nos. 1 and 2 commenced in April 1980, it was completed in August 1980. After the Lalbaug bridge was complete, the same steel cribs and acrow pipes were used for the girders of the Byculla bridge. This explains as to why the erection of centering for Byculla bridge did not start earlier.

(v) Prestressing

34. The four girders were to be prestressed. There were 17 cables in each girder. The stressing was designed to be done in three stages. Broadly stated, the profile of different cables was as follows :



Each cable was made of 12 wires ; the diameter of the cable being 7 mm.

Extension chart prescribes stretching of cables wire by wire from one end only. The extension chart (Ex. M-43) is the only document available to the persons supervising or stretching the wires. The extensions designed for each of the cables were these :

| | | | |
|--------------|----|----|------------|
| Cable No. 1 | .. | .. | 19-30 cms. |
| Cable No. 2 | .. | .. | 19-30 cms. |
| Cable No. 3 | .. | .. | 19-50 cms. |
| Cable No. 4 | .. | .. | 19-50 cms. |
| Cable No. 9 | .. | .. | 20-56 cms. |
| Cable No. 10 | .. | .. | 20-54 cms. |

35. The extension chart which is supposed to guide the foreman, who operated the jack and the Engineers, who supervised the prestressing operations omits to state these matters :

(i) While the extension chart prescribes stretching from one end, it does not guide the man on the site as to what he should do if the designed extension was not obtained from the jacking end.

(ii) The extension chart or any other document available at the site does not lay down that if designed extension is not obtained from the jacking end the wire should be stretched from the opposite end to make up the insufficient extension.

(iii) Since the extensions designed for each cable are different it stands to reason that the load must also be different. The load or pull applicable to each individual cable is not mentioned.

(iv) In the event of "restressing" from the opposite end the design does not state the load or pull that may be applied for the purpose of restressing.

The second stage of prestressing was to commence when the girder was 28 days old and before casting the deck slab. The pull or load to be applied is specified generally as variable between 4.80 to 5.20 tonnes.

(vi) Concrete Mix

36. The concrete mix for the Flyover at Byculla was designed by Mr. Thorat, who is said to be specialised in such work. The salient features of the concrete mix are these :

The grade of the concrete designed by him was M-350. A higher strength of M-380 or M-400 was not designed for the end blocks of the girder. The control factor prescribed by him was :

(i) Concrete batching by weight and not by volume.

(ii) Aggregate—by volume.

(iii) Supervision—normal.

Since concrete was for the prestressed girders, it is reasonable to assume that Mr. Thorat knew the mandatory requirements of I.R.C. for prestressed girders. The batching is always by weight and not by volume. The supervision is invariably special and not normal. Since sand was used directly, appropriate correction for the water content in the sand was made and for each batch 17.4 litres of water was prescribed.

(vii) Girders 1 and 2 are cast

37. On 5th September 1980 the Girder No. 1, which was at the Western end of the proposed bridge was cast. The work of concreting lasted between 10 a.m. and 8-30 p.m. The concreting was done by batching method. The record of the concreting work is in the Ghani Registers (Ex. M-19A to J). The relevant Ghani Register is Ex. M-19I. It records 298 batches of concrete. Immediately below the figure "298", there is the signature of the Junior Engineer. The following endorsement appears by the side of the signature :

"Two hundred and ninety-eight bags plus four bags for additional strength (M-400) in end blocks (10 per cent extra cement) i.e. $298+4=302$ bags.

(Signed) K. M. DESAI,
Sub-Engineer, Project."

I have quoted the endorsement because the additional strength (M-400) for the end blocks is claimed to have been given by the process of adding 4 bags of cement. I will examine the validity of this claim later in this report.

38. The second stage of prestressing of the first girder was scheduled to commence on 3rd October 1980. The first stage of prestressing of the Girder No. 2 was to commence on 30th September 1980. Meanwhile, on 22nd September 1980 the Girder No. 2 was concreted. The work of concreting was done between 9-50 a.m. and 7-50 p.m. As in the case of Girder No. 1 the concreting was by batching method. Three hundred and six batches of concrete were consumed. At the end of the record of the batches, there is this endorsement :

“Three hundred and six bags *plus* 6 bags for additional strength (M-400) in end blocks, *plus* 1 bag for loss of weight i.e. $306 + 6 + 1 = 313$ bags only. Total three hundred and thirteen bags only.”

The Girder No. 2 was supported on the centering system referred to in paragraph 33.

(viii) Prestressing—Girder No. 1—First Stage

39. The stretching of cables was designed in three stages. Ex. M-38C, which is the drawing provides the stages as follows :

First Stage : Cable Nos. 1, 2, 3, 4, 9 and 10. When girder is 6 days old and minimum strength attained is 230 kg./cm².

Second Stage : Cable Nos. 5, 6, 7 and 8. When girder is 28 days old and before casting deck slab.

Third Stage : Cable Nos. 11, 12, 13, 14, 15, 16 and 17. When girder is 60 days old and after deck slab is cast and before casting wearing coat, kerb and parapet.

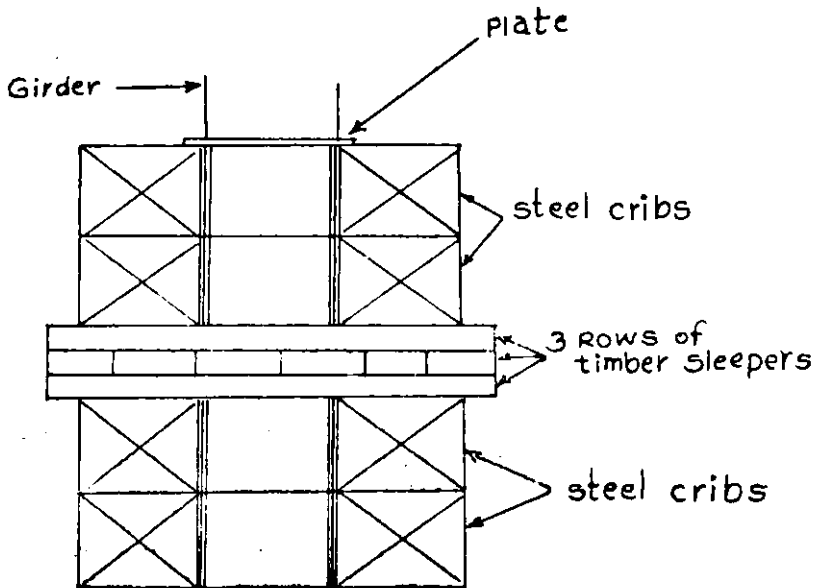
The seven days' strength of the concrete cubes was found satisfactory. Therefore, on 16th September 1980 the first stage of prestressing the girder was taken up. The Cable No. 1 was stretched on that afternoon. It took about three hours to stress Cable No. 1. The stretching of the Cable No. 2 was taken up on that day but it could not be completed. The prestressing was continued on 17th September 1980. The remaining five cables of the first stage were stretched from 9 a.m. on 17th September 1980 to 2 a.m. on 18th September 1980. According to Mr. Diwan, there was leakage in the oil from the jacking equipment. This caused delay in the work of stretching of the cables. No one from Killick Nixon & Company was present to supervise the work of prestressing. No Engineer having experience of prestressing cables was present during the entire duration of operations.

40. The extensions of various wires of the cables were recorded on loose sheets of paper by Mr. Paranjape (Con. W-2) on behalf of the Contractors.

Mr. K. M. Desai (M.W.-3) and Mr. Palshetkar (M.W.-5) also recorded them on loose sheets of paper. Thus, there were two sets of recordings of the extensions. On the following day these extensions were recorded in the Cable Stressing Book (Ex. M-16). Designed extensions were not obtained at the designed loads. Therefore, a large number of wires had to be stretched from the opposite end. Thus, if the cable did not receive the extension from North end, it was stretched from the South end so that the total of the extensions was nearly equal to the designed extension. However, the record of extensions from the opposite ends—described by witnesses as restressing—does not record the value of the load or the pull, applied from the opposite end.

(ix) Girder No. 1—Tilts along its axis—26th September 1980

41. On 18th September 1980 at 2-00 a.m. the stressing of six cables was complete. The Girder No. 1 was found to be self-supporting. The centering of the Girder No. 1 was, therefore, removed. Thereafter, the Girder No. 1 rested on the temporary crib stool system. The drawing of this system is at Ex. M-38B. This drawing brings out crib stool arrangement for supporting the girder on the portal columns until it is lowered to its final position. There is no date. No number. No Engineer has said that this drawing was approved. There are calculations submitted by Mr. Diwan in respect of this arrangement. The rough sketch of the temporary crib stool system would appear thus :



The Girder No. 1 rested on its North and South ends on the temporary crib stool support between 18th September 1980 when the centering was removed and 30th September 1980 when the girders collapsed.

42. At about 4-30 p.m. on 26th September 1980, Mr. Paranjape (Con. W-2) was standing on R.C.C. spans on the Southern side. He noticed that the Girder Nos. 1 and 2 were not completely parallel to each other. The Girder No. 1 had tilted along its axis towards the West. He was alarmed. He asked the carpenters to keep away from the site. He put boulders on the road to cordon off the site. On receiving his word Mr. Diwan, Mr. Joshi and Mr. Vedak arrived at the site at 7-45 p.m. They examined the temporary supporting system over the portals from underneath the girders and found that two sleepers from the middle layer and one from the top layer had cracked. This caused the tilt of the girder. Mr. Diwan considered the "fear psychosis" of the people at the site. He asked the labourers to keep away from the girder. Mr. Diwan advised that towers of steel cribs be erected, so that they would take the load of the two girders and relieve the temporary system of the load. Once the crib stool system was relieved of the load, the girder could be brought to vertical position. Meanwhile, as a temporary measure Mr. Diwan advised that gaps in the crib stool system be filled up by packing additional timber sleepers. Mr. Paranjape directed the carpenters to do so. According to the Contractors, solid packing was given on the Western side and "light packing" was given on the Eastern side. The tilt was apparently arrested at 20 mm. Mr. Umadi, Mr. Sanghadia and Mr. Desai were not present at the site as they had gone to attend the classes in "Design Mix" at Ghatkopar. Messages were sent to them. Mr. Umadi and Mr. Desai arrived at the site. Mr. Sanghadia could not be contacted. Messrs. Umadi, Desai and Palshetkar had discussions amongst themselves as also with Mr. Diwan. They too, agreed that as a temporary measure the packing of the crib stool system would serve the purpose. But they considered it necessary that the girder should be brought to vertical position. Mr. Diwan thought that the crib stool system should be relieved of the load. He conceived the idea of erecting two towers of steel cribs on which the girders could rest. Mr. Diwan, Mr. Joshi and Mr. Vedak went to the house of Mr. Kudal of Shenoy & Co., Contractors. Time was 11-00 p.m. on 26th September 1980. They must have left the site after instructing Mr. Paranjape to pack the gaps. From the house of Mr. Kudal, they went to the factory of Shenoy & Co. at Chembur. They could not secure cribs at both the places. They returned to the site. The work of packing the gaps by timber sleepers and props went on until 2 a.m. on 27th September 1980. However, similar packing and propping was done in the crib stool system at the North end. This was completed on 27th September 1980.

43. On the morning of 27th September 1980 Mr. Sanghadia and Mr. Desai met at the site and decided to insist that the Contractors remove the tilt and bring the girder to vertical position. Mr. Desai wrote the memorandum Ex. M-15A in the triplicate book. He recorded that the girder

had "slightly tilted" and that the tilted position was "not desirable". He, therefore, called upon the Contractors to bring the girder to vertical position "immediately". This memorandum was served on Mr. Paranjape around 12 noon. Mr. Joshi and Mr. Diwan came to know about the memorandum immediately.

44. In spite of the memorandum, no steps were taken by the Contractors to erect towers to support the girder and relieve the temporary system of its load. In other words, the girder was not brought to vertical position, by any method. Nor were any steps taken. In Ex. M-38A, however, there is design of a system of Trestle Towers for the purpose of lowering the girder to its final position, on the portal columns. The Girder No. 1 was proposed to be lowered around 3rd October 1980. The design of the Trestle Towers was available with the Contractors and Mr. Diwan. This was prepared long back in 1979. No steps to procure the material required for the towers appear to have been taken. According to the Contractors and Mr. Diwan it takes about 10 days to fabricate and erect towers of Trestles. The girder was to be lowered on 3rd October 1980. Therefore, the Trestle Towers had to be ready before 3rd October 1980. The necessary steps for this ought to have commenced at least on 26th September 1980. No such steps were taken.

(x) The two Girders Collapse—30th September 1980

45. The Girder No. 1 continued to exist in a precariously tilted position. Apparently, the tilt was measured every day. Nothing except watching the tilt was done. On the night of 29th September 1980, work in connection with the centering system of the third girder was going on at the site. Mr. Paranjape was in charge of the work. The workers, who had worked during the day time continued to work on the night shift as well (Para. 23 : G. D. Joshi, Con. W-3). Around 10-30 p.m. Mr. Joshi (Con. W-3) was at the site. In his presence Mr. Paranjape (Con. W-2) measured the tilt. There was no increase in the tilt. Mr. Joshi left soon after midnight. The labourers finished the work at 2 a.m. Mr. Paranjape (Con. W-2) had gone to switch off the electricity. The switch was a little away from the R.C.C. spans. While he was about to switch the current off he heard a loud noise. Initially, there was a single loud noise but the noise continued for 5-10 seconds (Para. 20 : Paranjape, Con. W-2). On turning back he found that both the girders had collapsed.

(xi) The Earthquakes

46. On 11th December 1980 Messrs. Model Construction Company, in consultation with Mr. Diwan, addressed a letter to the Director-General of Meteorology, New Delhi. The original letter has not been produced. The Director-General of Meteorology replied by his letter No. S-00402 (Appendix 'F' of Ex. C-6) dated 16th February 1981. The letter recalls

occurrence of certain earthquakes. The following table shows the dates, time, epicentre and magnitude :

| Date | Origin time in I.S.T. | | | Epicentre | | Magni- tude | Remarks |
|------------------------|--------------------------|----|----|-----------|------|----------------|---|
| | H. | M. | S. | N. | E. | | |
| 2nd September 1980 .. | 22 | 09 | 08 | 17.1 | 73.7 | 5.2 | Near Koyana Region (Felt in several places of Maharashtra). |
| 20th September 1980 .. | 12 | 58 | 55 | 17.2 | 73.7 | 5.2 | In Koyana Region (Reported felt in Bombay). |
| 20th September 1980 .. | 16 | 15 | 29 | 17.3 | 73.7 | 5.3 | In Koyana Region (Reported felt in Bombay). |
| 25th September 1980 .. | 19 | 08 | 25 | 17.4 | 74.2 | 4.9 | In Koyana Region (Reported felt in Bombay). |

The Director-General proceeds to state that 82 after-shocks from the Koyana Region were recorded at the Bombay Seismological Laboratory. These shocks were of much lesser intensity and *might not have been felt at Bombay*. Finally, the Director-General of Meteorology records that since the intensity decreases with the distance from the epicentre, the estimated intensity in the Modified Mercalli Intensity Scale was not likely to be more than II. No evidence of the earthquakes felt at Bombay and recorded in Bombay has been produced. These facts have to be mentioned because Mr. Diwan attributes the tilt of the girder to the earthquakes. The Panel of Experts on the other hand considers that the earthquakes were of such a low magnitude that they did not affect the Girder No. 1 or Girder No. 2.

PART II—*Concluded*

PART III

SEARCH FOR THE CAUSE OF COLLAPSE

I. SCHEME OF THIS PART

47. The evidence reveals that the main stages in the construction of the bridge are these :

- (i) Erection of centering system or the supporting system.
- (ii) Concreting or casting of the girders.
- (iii) Prestressing Operations.

The Report, of the Panel has examined all these aspects. But I am in duty bound to consider each of these processes independently and judge whether the cause of the collapse lies in any of these three stages of construction. The Report of the Panel will no doubt aid me as with the evidence of my witnesses. As a part of this investigation I will go into the questions of scientific validity of the operations carried on at the site. If during these investigations I find that any of these factors has not been responsible for the collapse, such factor will be eliminated as the cause of the collapse. The mass of evidence produced before me calls for a careful scrutiny of the manner in which the work in respect of each of these stages has been carried on. My endeavour, therefore, is to consider on the basis of the evidence, each of these stages with a view to locating and identifying the cause of the collapse and incidentally the method of working adopted by the Engineers concerned.

II. CENTERING OR SUPPORTING SYSTEM OF THE GIRDER

(i) General Principles

48. Most of the Engineers who have been at the site of the bridge have worked only on roads and buildings. None of them, with the exception of Mr. Diwan, has worked at any bridge site. In order to judge whether the supporting system of the Girder No. 2 was adequate and whether the cause of the collapse lies somewhere in this system. certain principles have to be borne in mind :

(i) Where timber ballies are joined end to end to create a long bally for vertical support, they should be properly spliced by taking into account, shear strength of the fastener and bearing and tearing strength of the timber splice.

(ii) Multiple number of joints in the ballies are not desirable. In view of the vulnerability of the bally to resist lateral forces, such joints diminish the load bearing capacity.

(iii) The age of the ballies is important. With every use of a bally for a centering system and the resultant damage caused by the use, its capacity to carry load with safety is successively reduced.

(iv) Though the principles of design of bridge centering and formwork are not different from those of buildings, there are certain differences in the details :

(a) In the case of bridge-centering, the dead loads are of considerable magnitude.

(b) Due to the exposed nature of the bridge site, the centering of a bridge has to withstand forces like wind pressure.

(c) The height of the centering of a bridge is normally much more than the height of the centering for a building. The system needs to be properly conceived having regard to the nature of the bridge, its load magnitude and the other forces acting on the system.

(v) The horizontal forces which cause sideways due to construction activity are of considerable magnitude. Such forces have to be taken into account by the designer.

(vi) In the design of timber centering, having regard to a large number of vulnerable joints and its constructional imperfection, as compared to steel centering, it is advisable to design it as a statically complete frame by providing inclined shores spiked in ground at ends for resisting the sideways instead of designing it for increased stresses which allow sideways.⁵

(vii) The timber ballies should be uniformly erect. The non-uniform erectness of timber props causes eccentricities of load points causing sideways and resultant buckling.

(viii) The behaviour of centering where the concrete is laid should be carefully watched. Every unusual behaviour/instance should be watched and taken care of. It may be a forewarning of the possible failure.⁶

(ix) Bamboo is not a good material for use as bracing, if it is nailed to the vertical prop.

(ii) Design of Centering

49. The drawing of centering system (Paragraph 33) for Girder No. 2 has been referred to earlier. Broadly stated, the centering system consists of round ballies resting on cross wooden sleepers laid across longitudinal rolled steel joists. These rolled steel joists are in turn supported on columns of steel cribs, which rest on the ground. The columns are at a distance of 8 feet centre to centre along the length of the girder. Each column is built over four steel cribs mounted one over the other.

The steel cribs are connected by clamps. The timber sleepers and R.S. Joists below them are not fastened to each other.

⁵ " Failure of centering on some bridge works."—Article by Mr. A. G. Namjoshi, *Indian Highways*, published by Indian Road Congress—November 1960.

The design does not show that there is any support of timber scantlings or wooden props which held the R.S.Joists in position, so that they are not displaced.

The design provides horizontal bracings by 25 mm. diameter bamboos. The report of the Panel of Experts appointed by me has in Paragraph 4.5.0 found that the system of centering of Girder No. 2 was not desirable. One of the reasons for their conclusions may be summarised thus :

A combination of steel cribs, R.S.Joists, timber sleepers and wooden scantlings create several hinge-like joints in vertical planes. Unless there are adequate lateral bracings, such a system is vulnerable to horizontal loads. The system is made up of layers of different material. There is nothing which held all these layers together.

50. Mr. Diwan, who is experienced and claims to be original in his thinking and approach was questioned by his own advocate with reference to this aspect of the report (Paragraph 24 : Mr. Diwan, Con. W-1). His opinion is in clause (d) of Paragraph 24. He merely denies that any "hinge-like" joints are involved in his design. He does not answer the fact that the system of centering conceived by him is made up of layers or tiers of cribs, R.S.Joists, sleepers and ballies. A mere look at his design reveals joints :

(i) between the top of the crib and the R.S.Joists, which are not held together by any device.

(ii) at the point of contact of the bottom of the timber sleeper and top of R.S.Joists.

(iii) at the point of contact between the bottom of the timber ballies and the upper surface of the timber sleeper.

Mr. Diwan has made no attempt to explain as to why these points are not "hinge-like" joints. The word "hinge-like" has been used to describe the nature of the joint. These joints are not firm and unmovable. The frame of centering is vulnerable at these joints. It is in this sense that the Panel has used the word "hinge-like". In the face of these facts and absence of any rational explanation, Mr. Diwan's denial is arbitrary. Denial does not demolish the existence of these facts.

51. He characterises his system as "composite system". He then goes on to claim that his system is advocated by I.R.C. Guidelines (Ex. Con.-4) These guidelines have been published and circulated by the Indian Road Congress and opinion is sought. They have yet to come into force as a Code. They do not have the force of the I.R.C. Codes. But since these guidelines are proposed to be transformed into I.R.C. Code the ideas which find expression in them may be assumed to be ideas of men of learning in the field of Civil Engineering. I am willing to look into them as words of wisdom expressed by members of the Indian Road Congress. It will appear from subsequent discussion that these guidelines not only do not advocate the system designed by Mr. Diwan but indeed repudiate it. Mr. Diwan and his advocate have not pointed out as to how the guidelines support his system of centering.

52. The design of Mr. Diwan does not state that any steps to prevent displacement of R.S.Joists were taken. He has referred to support by props from the angles of the cribs. According to him, these props and scantlings were tied to the R.S.Joists. The design of the centering does not bring out this fact. The explanation which has come out in the cross-examination appears to be an after-thought. The Engineers of the Corporation and Mr. Paranjape were in the witness box for a long time. None of them have stated that such supports were in fact given. Mr. Paranjape (Con. W-2) was examined after Mr. Diwan. If supports were given he would have stated so. I reject Mr. Diwan's statement that props and scantlings supported the R.S.Joists.

53. The report of the Panel in relation to the scientific desirability of the centering system designed by Mr. Diwan is thus unchallenged. In a matter like this where facts have to be found a mechanical approach of rejecting evidence merely because it is not challenged by the cross-examiner, who is not an Engineer is not sound. I have, therefore, endeavoured to search for rational and intrinsic evidence of the validity of the opinion of Experts.

First : The layers, cribs, R.S.Joists etc., are loose. It is rational to hold that such a structure is not firm, compact and unshakable. Its vulnerability is writ large in the design.

Second : Loose and un-connected joints have a tendency to be displaced by loads.

Third : No rational hypothesis to prove that the system is stable and unyielding has been suggested.

Fourth : Mr. Diwan claims that props and scantlings were used to support R.S.Joists. This implies that without such support the system was not firm, sound and safe.

These four reasons are of intrinsic nature. By its very nature the whole structure of centering was loose and unsafe. Mr. Diwan realised this. That is why he asserts additional support by scantlings.

The Panel of Experts has not held that failure of this system caused the collapse. Dr. Gupchup (C.W.-1) (Paragraph 49) has conceded that the Panel examined the soundness and safety of the system. What they mean is that the quality of centering is not desirable for a girder of such a magnitude.

54. There is cross-examination of Dr. Gupchup on behalf of the Corporation. The attempt was to establish that the Corporation was justified in approving the design of centering of the Girder No. 2. Following justifications were suggested on behalf of the Corporation :

(i) A timber bally, which is well spliced can carry 60 per cent of the load.

(ii) The horizontal forces acting on the Byculla site were of the order of 10 per cent. The vertical load of 72 tonnes acting on the props would counteract the small amount of horizontal forces because of the friction. It would require more than 10 per cent of the load to displace the R.S.Joists.

These points are valid. The evidence of Dr. Gupchup (C.W.-1) leaves no doubt that if the friction between different components could prevent displacement of the components like R.S.Joists, design itself was viable though not desirable. In approval of designs, economy is undoubtedly a factor but economy at the cost of safety has to be discouraged. The magnitude of the work, costs involved, the possible damage resulting from failure have to be borne in mind. The use of a system of timber ballies may be economical. It is not forbidden by any Code of the Engineering profession. But such a weak, vulnerable and intrinsically unsafe system of centering is undesirable.

(iii) Material used

(a) Bamboo Bracings

55. The design of the centering system (Ex. M-38F) provides as follows :

- (a) 75 mm. diameter ballies at 3 metres distance centre to centre.
- (b) Horizontal bamboo bracings at a distance of 600 mm. centre to centre.
- (c) Diameter of the horizontal bracings 25 mm.

Mr. Diwan (Con. W-1) and Mr. Paranjape (Con. W-2) have admitted these facts :

- (i) The bamboo bracings were fixed at a distance of 450 mm.—contrary to the design.
- (ii) Bamboo bracings had diameter less than 25 mm.—again contrary to the design.

Thus admittedly two deviations from the design. I do not suggest that this deviation by itself was fatal to the system. But scientific validity of the centering system is being examined. It is the work of a Consulting Engineer, who claims extensive experience and learning. It is not unreasonable to expect that the work of an Expert Engineer conforms to his own design. Mr. Diwan (Con. W-1) has come forward with two explanations :

- (i) The variation from the design is on the safer side inasmuch as the bracings were fixed much closer to one another.
- (ii) Wherever bamboos of smaller diameter were used, two bamboos were made to overlap each other, thereby making the bracing effective.

56. In view of the evidence, the explanations given by Mr. Diwan are untenable. I shall state how. In paragraph 78, Mr. Diwan was questioned with reference to the centering system. The reason assigned by him for the deviation from the design is this :

“The diameter of the ballies which I brought on site was narrower than what I had expected. Therefore, I altered the distance between the bracings by reducing it to 450 mm.”

If this were the only reason it would be difficult to find fault with the deviation. The Engineer at the site faces diverse problems. They have to be understood. While strict bookish adherence to the design may not be always possible at the site, it should not be ignored that design is intended to aid sound execution of work. If the cross-section of the timber ballies was smaller why was care not taken to purchase timber ballies of the required cross-section? There is no explanation. It should be remembered that Mr. Diwan has earlier stated that in designing the system he had taken into account the availability of the material. Therefore, a question arises—if design was prepared after considering availability of material, why was unsuitable material used? He was asked about this in the same paragraph. I quote his answer :

“I did so on the basis of my personal judgement and experience on site work.”

This is an admission that he has no explanation as to why he varied the distances between the bracings. He has once again resorted to irrational and arbitrary process of explaining away inconvenient facts. Thus he had ballies which had smaller cross-section. The bamboos too had smaller diameter. The work at the site was done contrary to the design in order that it suited the unsuitable material secured by the Contractors. Mr. Diwan's claim that distances were altered to make the system safe is untenable.

57. There is one more significant fact. Mr. Diwan had submitted design calculations in respect of the centering of the design. While making these calculations and preparing designs, designer has a right to make certain assumptions. The Corporation, who have to approve the drawings and the design calculations rely upon the calculations. The approval of the design by the Corporation is materially influenced by the soundness of the assumptions and the calculations. Admittedly, in the design calculations, Mr. Diwan had shown the distance between the bracings as one metre and the diameter of the bamboos was assumed to be 1 inch or 25 mm. On these assumptions and calculations, Mr. Diwan secured the approval of the design. He was not right in altering the work by using material of different diameter. The approval of the design was secured by representation of facts contained in the drawings. In execution of the work the assumption that bamboos and ballies will have previously disclosed diameter was given up. In a sense, the Corporation was misled into approving the design.

The last aspect of the centering system is the fact that a large number of bamboos fixed as bracings were split at nail points. It is a scientifically established fact that bamboo is not good bracing material if it is nailed to the bally. A split bamboo cannot transfer the load. Mr. Diwan with his extensive experience ought to have known that there is no way of transferring load through the split portions. The capacity of bracing material to hold on to the timber ballies by means of nail depends upon the bearing stress of the bamboo. In the calculations submitted to the Corporation the bearing stress of the bamboo was not taken into account (Mr. Diwan, Con. W-1, Paragraph 75). The bearing stress assumes importance because the bamboos were nailed to the ballies. The original drawings or calculations do not show that the bamboos were proposed to be nailed. Had the drawings disclosed that bamboos were to be nailed, the Corporation would have hesitated before approving the design and in all probability they would have sought correction of the design.

58. Mr. Diwan's testimony on this aspect is false to his knowledge. He continued to assert that a split bamboo is a good bracing. He was given opportunities of retracing his step and giving a scientific account of facts. Yet he says this in paragraph 75 :

“I do not agree that a split bamboo is not a good bracing ; the value of the bamboo which is split depends upon the point at which it is split.”

Indeed, he implies that a split bamboo is good bracing material. He has come out with a new theory that the unfavourable effect of split caused at the nailing point is corrected by bending the nail and hammering it at the same point. He does not explain as to how the result of the split is averted by this process. He refuses to recognize that the split part fails to transmit the load. But having seen him in the witness box and having known his approach, it appears to me that his evidence about the bending of the nail and hammering it into the bamboo is an after-thought. It is proved that a split bamboo fails to transfer the load. Mr. Diwan's evidence is not only untrue but is based on unscientific assumptions.

The upshot of his evidence is thus :

“Bamboo may split at the nail point. Its bearing stress may not have been taken into account. But at the site this was corrected by bending the nail and hammering it at the same point.”

Whether this assertion is valid or not, the method required to be explained to the man at the site. Mr. Diwan himself did not hammer the nails at the site. His drawings do not contain any instructions to the Site Engineer and the carpenters that this should be done wherever the nail splits. In his evidence he does not say that he was present at the site throughout. I am afraid, Mr. Diwan has made untrue statements merely to hold on to his erroneous and irrational opinion. His evidence is an exercise in sophistry.

59. Mr. Diwan is an experienced Engineer. I do not wish to be critical of his ideas. A single individual is entitled to hold his views against the rest of the World. I should ordinarily hold Mr. Diwan's views with utmost respect. An original approach, freshness of thought and dynamism are great virtues. They need to be encouraged and usefully harnessed. But he resorts to such irrational thoughts and sophistry that it is not possible to accept some of his views. In the "Guidelines" which he himself produced (Ex. Con. 4) "Timber ballies" has been described as one of the material for bracings (please see Table 3-4). But Mr. Diwan says this :

"There is no rule that ballies should be used as bracings. On the other hand I consider that bamboos are better suited as bracings."

His attention was drawn to the fact that in the guidelines, which are proposed to become I.R.C. Code, there is a Chapter on "Materials" and that in the Guidelines bamboo has not been referred to or suggested as a material suitable for formwork. Wood and timber have been referred to as such material. Mr. Diwan asserts that bamboo is included in the meaning of timber or wood. He refuses to accept the plain meanings of the words "Wood", "Timber" and "Bamboo". It is elementary knowledge that wood is a generic expression which signifies "the hard compact fibrous substance between pith and bark of trunks and branches of trees, whether growing or cut for timber or fuel". Timber on the other hand is a specific form of wood. Timber is wood prepared for building carpentry etc. "Bamboo" is a species of grass in the same way that sugar-cane is species of grass. The word "Bamboo" has its origin in its generic Botanical name "Bambusa". Bamboo is a hollow jointed stem used as stick or material or food (please see the Concise Oxford Dictionary of current English, 6th Edition). On any view of the matter, Mr. Diwan is wrong in his opinion that Bamboo is timber. The guidelines of I.R.C. do not support his view that bamboo is a material which should be used in any formwork.

I have no doubt that the Panel of Experts was justified in characterising the centering system as undesirable.

(b) Timber Ballies

60. The decision to hold inquiry by Mr. R. T. Atre was announced on 1st October 1980. The work of clearing debris continued until the evening of 1st October 1980. In view of this decision, the Contractors were asked to stop the work of clearing. The Contractors were aware that the tilt was caused by cracks in three timber sleepers. It is not clear as to why they did not preserve the cracked timber sleepers. It would have been better had they preserved them for examination by Experts. No explanation is offered for the failure to preserve the sleepers. Similarly, the centering material like timber ballies which were about 400 in number were removed from the site. Appendix 'B' to the report of the Panel of

Experts contains the analysis of the timber ballies found at the site. The statement below gives a summary :

| At the site of collapse | | In the North Godown | In the South Godown | Broken ballies | Total |
|-------------------------|------------------------------------|---------------------|---------------------|-----------------------|-------|
| In a single stack | Between collapsed girder and cribs | | | | |
| 181 | 53 | 68 | 47 | 59 | 408 |
| Average length | | Average length | | | |
| 4.30 M to 4.45 M | Length not mentioned. | 0.65 M to 4.20 M | 1.50 M to 2.70 M | Length not mentioned. | |

61. The total number of ballies found at the site was 408. About 240 ballies were used under the girder. A total number of 400 ballies seem to have been used for the gangways and underneath the girder. It is suggested that though bent and spliced ballies were found at the site, all of them were not used under the girder. Indeed an exaggerated statement that all the ballies used under the girder were in excellent condition has been made. Spliced ballies are stated to have been used at the outer rows under the girder. I will presently examine the validity of this claim made by the Contractors. Mr. Desai (M.W.-3) (Paragraph 5) has stated that the girder was cast at the height of 7.3 metres from the ground level. Ex. M-38F shows that the height up to the level of the timber sleepers from the ground level was 2.7 metres. If 2.7 metres are deducted from the total height of the girder at the time of casting it, a height of 4.6 metres is left. Therefore, the timber ballies used under the girder had to be about the length of 4.5-4.6 metres. The 47 ballies (length 1.50 M. to 2.70 M.) found in the South godown and the 59 broken ballies found at the site will have to be excluded. These ballies by reason of their height were incapable of being used for centering. But the height of the broken ballies or their length have not been measured. I will give the benefit of this omission to the persons in charge of the work. After excluding these ballies, 331 ballies are left. The 68 ballies in the North godown had length between 0.65 m. and 4.20 m. All of these were not capable of being used for centering because of their length. Some of them were. If 30 of these are excluded as being unsuitable for centering work, 300 ballies are left. I will assume that out of the 408 found at the site, 300 were capable of being used for centering work. Were these ballies fit for being used for centering work? The analysis made by the Panel in Appendix "B" reveals that only 53 ballies were straight and good. The central row would need 80 ballies. Since only 53 were found straight, erect and unspliced, it is clear that 27 ballies in the centre were not straight, erect and unspliced. This destroys the claim of the Contractors that spliced ballies were not used in the

The claim that the spliced ballies were used only in the outer rows and for gangways appears to be farfetched, exaggerated and designed to impress that the centering system was good.

62. Mr. Paranjape (Con. W-2) was the person who physically verified the timber ballies. He asserts that all the ballies used below the second girder were straight and erect. Having regard to the percentage of spliced and bent ballies, I do not think that the contractors' assertion that all the ballies used under the second girder were straight and erect is well founded.

There is circumstantial evidence which suggests that timber ballies were not satisfactory. Look at these facts :

(i) These ballies were checked physically by Paranjape (Con. W-2) when they were used under the R.C.C. spans. Therefore, the very same ballies were used under the Girder No. 2.

(ii) On 2nd September 1978 a complaint that ballies used under R.C.C. Span were bent and decayed was made (Ex. M-15).

(iii) On 21st September 1978 similar complaint about the inferior quality of ballies was made.

(iv) Ballies were used ballies (Umadi M.W.-2, Paragraph 27)

(v) Sub-Engineer Mr. Nadkarni complained to the Contractors that the propping arrangement of the Slab No. 18 was defective inasmuch as some props were thin and deformed.

These circumstances furnish evidence of the quality of timber ballies. The complaints by themselves do not constitute evidence about these ballies. It is the evidence of Mr. Paranjape (Con. W-2) that connects the complaints with the ballies used here. He does not say that ballies used under the R.C.C. Span were different from the ballies used under the girder. Indeed he says that he examined these ballies when they were used under the R.C.C. Spans. The circumstantial evidence of past complaints and the quality of ballies found at the site together with Mr. Paranjape's evidence in paragraph 16 leaves no doubt that inferior and unsuitable timber ballies were used under Girder No. 2.

(c) Timber Sleepers

63. In all 246 timber sleepers were found at the site and in the godowns. The only significant material about the quality of timber sleepers is in the oral evidence of Mr. Desai (M.W.-3) and Mr. Diwan (Con. W-1). They have admitted that a number of sleepers were cracked. Both of them have stated that the cracks were superficial. Timber sleepers collected at random were tested in the Laboratory of V.J.T.I. The test reports are at Appendix 'H' to the report (Ex. C-6). The samples tested by the Panel appear to be satisfactory.

64. The classification made by the Panel does not show that timber sleepers were visually examined for finding out the number of cracked sleepers. However, Mr. Desai (M.W.-3) and Mr. Diwan (Con. W-1) have admitted that a number of sleepers used at the site were cracked. They hasten to add that these cracks were superficial. In the absence of any evidence about the depth of the crack it cannot be held that timber sleepers used for centering were necessarily of inferior quality. But the fact that cracked sleepers were used by the Contractors has to be borne in mind for considering the crib stool system.

(d) Steel Cribs

65. Nothing adverse has been found in respect of the Steel Cribs.

(iv) Temporary Crib Stool System

66. A rough sketch of the Temporary Crib Stool System on which the Girder No. 1 rested over the portals is in paragraph 41 *ante*. It is a two-tier system erected over each of the portal frames. This system supported the Girder No. 1 at the articulated ends at a height of about 2.3 metres. After the first stage of prestressing was over, the centering was relieved of the load of the girder. This temporary system, therefore, carried the entire load of Girder No. 1. A similar system was used for supporting the Girder No. 2.

67. Three layers of wooden sleepers were interposed between the two tiers of steel cribs. The layers of timber sleepers were approximately at mid-height of the whole system. The moduli of elasticity of steel and timber are different. Their strains of incompatibility are also relevant. However, the designer chose to have a structure of this kind to support the 72 tonne girder with three layers of timber sleepers exactly at the mid-height of the system. The detailed consideration of this system will be found in paragraphs 152-160 *post*.

68. The design calculations in respect of this system are at Appendix 'D' to the report of the Panel of Experts (Ex. C-6). In addition to the temporary sleepers and two layers of steel cribs, vertical props were also introduced inside the cribs. The design calculations of the Contractors' Consultant mention the diameter of this prop as 2½". Their number shown in the calculations is four. Therefore, this system consisted of two tiers of steel cribs with three layers of temporary sleepers between them and four vertical props inside the cribs.

But the Panel of Experts during its investigation requested the Contractors to bring out in a sketch of the Crib Stool System and the additional support given to arrest the tilt. This was on 22nd May 1981. In this sketch, the Contractors have shown that there were eight props inside the steel cribs. This is a distinct improvement from what was originally designed. I will examine later on whether eight props were actually used in the system.

(v) Conclusion of Centering System

69. (i) The centering system designed by Mr. Diwan is not desirable for reasons already stated. The conception of a system having joints may not be forbidden. But in practice, it is undesirable. Such a system is vulnerable to horizontal forces and ought to have been avoided.

(ii) The design calculations were made on the assumption that bamboo bracings would be of the diameter of 1", whereas at the site bamboos of lesser dimensions were used.

(iii) The design specified timber ballies of 75 mm. diameter. During execution narrower ballies were used.

(iv) Bamboo is unsuitable for bracing. The bamboos were split at the nailing points thereby rendering them ineffective. Bamboo bracing should not have been used.

70. For the reasons stated by me, I accept the findings of the Panel that the centering system was not desirable. The centering of Girder No. 2 withstood the forces during concreting. No damage was done until 30th September 1980. Therefore, the centering system though undesirable did not cause the collapse of the girders.

71. The various aspects of centering have been gone into for the purpose of investigating whether the centering of the Girder No. 2 had anything to do with the collapse. The fact that girder did not collapse in spite of such a centering does not make it a good system. The conception of this system is unsound though the system stood the forces resulting from concreting and vibrations.

III. CONCRETE

72. No fault could be found with the quality of the concrete. This is borne out of the results of the Core Tests and the Report of the Panel. But, in the process of concreting as in other processes of construction, methods adopted are not scientific. The mix design prepared by Mr. Thorat does not provide for a higher strength for the end blocks of the girders. But Mr. Diwan, the Consulting Engineer has stated that the end blocks require more strength and that it was his idea to increase the strength to M-400 so far as the end blocks of the girder are concerned. For this purpose he suggested that 10 per cent extra cement be added, so that the end blocks attain the strength of M-400. In paragraphs 37 and 38, I have set out extracts from the Ghani Register No. 9 (Ex. M-191). In the case of Girder No. 1, four additional bags making approximately 10 per cent of the total strength of cement were added. But in the case of Girder No. 2 six additional bags were added. This does not make 10 per cent of the quantity of the total cement used. Here also no consistency is maintained. Mr. Diwan has explained that the concrete was laid throughout the length and breadth of the girder layer above the layer. But then the claim that additional strength to the end block was given by adding 10 per cent

extra cement becomes unfounded. Consider the evidence of Mr. Desai (M.W.-3), who was at the site throughout. He says that the first 40 batches of the concrete mix would cover the end blocks. The stage at which the additional 4 and 6 bags of cement were added is not stated. Mr. Desai (M.W.-3) does not say that these bags were added to the concrete mix which was consumed by the end blocks. Mr. Desai (M.W.-3) says this :

“ I agree that this amount of cement would not give a strength of M-400 but it could be less or more. I have not mentioned in the Ghani Book that this additional 10 per cent cement was added in any particular batch meant for the end blocks. From the record of batches I cannot state that the end blocks received the additional cement.”

In view of these admitted facts, Mr. Diwan (Con. W-1) is not right in his claim that the addition of 10 per cent extra quantity of cement provided strength of M-400. Though the Ghani Register is written by the Site Engineers, Mr. Desai and Mr. Palshetkar, the concept of additional strength for the end block belongs to Mr. Diwan. The unscientific work therefore, originated from Mr. Diwan. The Site Engineers merely supervised the execution of Mr. Diwan's idea. Nothing more be said on this aspect because in the result the concrete used was excellent but the method was unscientific.

IV. PRESTRESSING

(i) General Principles

73. The idea of prestressing was conceived by the French Engineer, Mr. M. Freyssinet. Prestressing means the intentional creation of permanent stresses in a structure or assembly for the purpose of improving its behaviour and strength under various service conditions. (“ Design of Prestressed Concrete Structures ”, Second Edition, by T. Y. Lin). The basic principle of prestressing is to produce, by any suitable means, sufficient compressive stresses in all those parts of the concrete where tensile stresses would occur, when the external loads are applied. When prestressing is applied to concrete effective internal stresses are induced artificially, usually by means of tensioned steel, prior to loading the structure.

74. In the process of prestressing there is a likelihood of slip caused by the cable slipping from the jacks or the wedges. The designer has to account for it in his design.

75. During the process of prestressing “ hogging ” takes place. In this process, which is natural in prestressed girders, the load of the girder is shifted towards the two abutments. The supporting system must, therefore, take into account this transfer of load.

76. The cables must be so stretched that they are extended to the designed degree. Insufficient extension means inadequate prestressing and may cause failure.

77. Stress induced in the concrete creates pressure. Therefore, stressing of the cables should be so done that uniformity of the stress is maintained. Eccentric location of the stress means unequal pressure. This inequality of pressure may cause distress.

78. The stressing should begin from the central cable and the alternate cables should be stressed to maintain the uniformity of pressure. If a cable at one end is stressed, its counterpart on the opposite side should be stressed, so that equilibrium is maintained.

79. The initial prestress undergoes some reduction due to the loss of prestress, which results from the shrinkage of concrete and creep of concrete and steel, shortening of concrete at transfer, friction and anchorage slip. These losses need to be estimated and taken into account while preparing designs, so as to maintain working prestress sufficient to produce the designed compressive stress in the concrete.

80. When tendons are stressed, it is not possible to obtain exact elongations according to the design. Variations are natural. But the variations in the elongation of individual wires should be within the range of 5 per cent.

81. Cables may be stressed either from one end or both the ends. In the case of girders which are long, it is advisable to stretch the cables from both the ends simultaneously.

82. The adequacy of the prestress is of the essence in judging stability of the structure. If the variations exceed permissible limits the stress may not be adequate. This, in turn, may frustrate the very purpose of prestressing.

(ii) Design of Prestressed Work

(a) Drawings

83. Details of prestressed concrete girder are in the drawing No. MC/BYC/16, dated 25th November 1977 (Ex. M-38C). The following features of the drawing are noteworthy :

(i) The prestressing was to be done in stages.

(ii) The first stage consisted of extension of Cable Nos. 1, 2, 3, 4, 9 and 10, when the girder was six days old and had attained minimum strength of 230 kg./cm².

(iii) Each cable was of 12 wires and the diameter of the cable 7 mm.

(iv) The ultimate Tensile strength of the cable prescribed was 150 kg./mm².

(v) The second stage of prestressing was to commence when the girder was 28 days old and before casting the deck slab.

(vi) Ex. M-38C directs attention to the Cable Extension Chart for jack pressure and extensions, neither of which are given in Ex. M-38C.

(b) *Extension Chart*

84. The Cable Extension Chart (Ex. M-43) has the following features:

(a) End Blocks cast *in situ* to achieve strength of 280 kg./cm.² before the first stage of prestressing.

(b) Cable to be stretched wire by wire from one end for extension as given.

(c) The pull of load to be applied shall be between 4.80 tonnes to 5.20 tonnes, but shall not exceed 5.5 tonnes.

(c) *Omissions*

85. I have summarised above the substance of what these two documents state. These documents are extremely important to the persons working at the site. These documents fail to bring out certain important factors, e.g. :

(i) Though the length of the girder was 36 metres (120'), the Cable Extension Chart, which is the basis of extensions, does not provide for stressing from both the ends.

(ii) Cable Nos. 9 and 10 were respectively designed to receive extension of 20.56 and 20.54 cms. But the load to be applied to them is not different from the loads to be applied to Cable Nos. 1 and 2, which were to receive extension of 19.30 cms.

(iii) Though the wires were to receive different extensions the load required to be applied to each wire has not been stated. Instead, minimum and maximum load has been prescribed.

(iv) There is no direction to the person at the site as to what he should do if he is unable to get the designed extension with the load specified in the extension chart.

(v) The drawing does not state that on failure to get the designed extension from one end of the girder, the person at the site should stretch the wire from the opposite end.

(vi) Nor does the drawing specify the load that should be applied if the wire is stretched from the opposite end.

(d) *Unapproved Change*

86. There is an important letter written by the Deputy City Engineer to the Secretary of the Commission. The letter bears No. CE/492/Proj., dated 16th April 1981. The truth of the statements made in this letter has been admitted by the Contractors during the course of evidence. The letter reveals the following facts, which must be taken to have been admitted :

(i) Originally, the Contractors intended to stress the Cables from both the ends.

(ii) The calculations of elongations for stressing from both the ends were submitted and were approved.

(iii) The Consulting Engineer of the Contractors decided to change the method of extensions. He decided to stress the Cables from one end only. Accordingly, the calculations were modified to suit the change.

(iv) The Revised Elongation Chart (Ex. M-43) was submitted just before the prestressing operations commenced.

(v) The Corporation did not allow the Contractors to proceed with the prestressing operations according to Ex. M-43. The Consulting Engineer took the full responsibility for the correctness of the Revised Extension Chart (Ex. M-43).

(vi) The Revised Extension Chart (Ex. M-43), which was not approved by the Corporation was followed at the site for actual prestressing of the Cables.

(e) Unsatisfactory Design

87. The facts which emerge from the documents referred to in the previous paragraphs require to be carefully considered. While dealing with a work where scientific processes are employed, execution of the work in a scientific manner should be insisted upon. Having regard to the facts summarised in the previous paragraphs and the general principles of prestressing, I am of the opinion, that the manner of prestressing designed by Mr. Diwan is hardly commendable. My reasons are as follows :

(a) He ought to have given the calculated pull or load for each Cable and then proceeded to prescribe the maximum limit of overstress.

(b) As a result of the failure to do this, the persons who actually operated the jacking equipment and recorded the extensions were left in the dark as to the exact forces to be applied to a particular wire.

(c) In the case of long girders it is a sound practice to extend the Cables from both the ends. This is established by the evidence of Dr. Gupchup. In paragraph 51, Dr. Gupchup (C.W.-1) enunciates the principle in these words :

“ In the case of girders of the length of 120, it is sound practice to extend the wires from both the ends simultaneously. The method of stressing simultaneously from two ends is related to the length of the girders ”

88. It is not uncommon that the designed extensions are not obtained with the designed loads. Mr. Diwan (Con. W-1) failed to guide the man on the site properly by specifying in the extension chart the steps that he should take in such a case. It was not difficult for him to write in the notes on the Extension Chart that if the designed extensions were not obtained the wires should be stretched from the opposite end. This was necessary because Mr. Diwan knew that the prestressing work was, in this case, done by persons without experience.

89. On the whole, the manner in which the man on the site was asked to stretch the Cables and omission of certain important factors in the Extension Chart left the man at the site to guess what should be done. The work of designing prestressed work is required to be done in an expert fashion. I do not think that this has been done in this case. Therefore, the quality of the design of prestressing is far from satisfactory.

(iii) Extension of Cables

(a) Standard of Supervision

90. The authority of the Codes of Indian Road Congress has been admitted and indeed everyone concerned with the bridge claims to have adhered to the Codes.

The British Standard Code of Practice for Prestressed Concrete assumes that the design of prestressed concrete is entrusted to Chartered Structural or Civil Engineers experienced in the structural use of concrete and that the execution of the work is carried out under the direction of a competent Supervisor. The Supervisor should not only be familiar with the technique of making high quality concrete, but should also be experienced in the various stressing operations involved. The Code goes on to emphasize that the stressing operations should be carried under his *direct supervision*. (A Guide to the B.S.Code of Practice for Prestressed Concrete No. 115 : 1959—by F. Walley and S. C. C. Bate—published by Concrete Publications Limited, London.)

The Indian Road Congress Code No. 18 of 1977 in its introduction emphasizes in mandatory language the importance of supervision of the work of prestressed concrete road bridges :

“The design and construction of road bridges require extensive and thorough knowledge of the science and technique involved and should be entrusted *only to specially qualified Engineers with adequate practical experience in Bridge Engineering* and capable of ensuring careful execution of work.” (Emphasis supplied.)

The authors of the Code also assume that “The execution of the work will be carried out under the direction of a competent Supervisor.”

Then the Code goes on to explain what is expected of such a Supervisor. To quote their words from the Introduction :

“The Supervisor should not only be familiar with the technique of making high quality concrete but *also be experienced in the various stressing operations involved*.” (Emphasis supplied.)

Therefore, the Code expects the persons in charge of the Supervision and Construction of prestressed concrete bridges to possess the following qualifications :

(i) Engineering qualifications with adequate practical experience in bridge building.

(ii) Familiarity with the technique of making high quality concrete and experience in the various stressing operations.

(iii) Extensive and thorough knowledge of the science and technique involved in prestressed concrete bridges.

In this part of the report, I will examine whether the supervision and construction of the bridge was left in the hands of such persons.

91. The Panel of Experts appointed by me had no occasion to consider this. Their terms were limited to discovering the cause of the collapse.

(b) Inexperienced Personnel

92. The prestressed concrete bridge at Lalbaug was the maiden experience for Mr. Nawathe (M.W.-1), Mr. Umadi (M.W.-2), Mr. Desai (M.W.-3), Mr. Sanghadia (M.W.-4), Mr. Palshetkar (M.W.-5), Mr. Paranjape (Con. (W-2) and Mr. Joshi (Con. W-3). They were all new to the construction of the prestressed girder bridge. It is, therefore, safe to conclude that so far as these persons are concerned the work was left in extremely inexperienced hands. But this is no fault of theirs. As employees they were not in a position to choose. They were bound to work at the site. The Corporation knew that its Engineers had no experience of such work. The Corporation while awarding the contract to Messrs. Model Construction Company took care to see that a consulting Engineer was engaged to supervise and ensure scientific execution of work. Indeed, the contract between Mr. Diwan (Con. W-1) and Messrs. Model Construction Company together with the admission of Mr. Diwan (Con. W-1) establishes that Mr. Diwan was concerned not merely with the design aspects of the work but with the actual construction of the bridge. I will evaluate the qualities of supervision of the work.

(c) Consulting Engineer, Mr. Diwan (Con. W-1)—Value of his evidence

93. Mr. Diwan (Con. W-1) is undoubtedly a Construction Engineer experienced in the work of bridges. But as already stated, his experience on the few bridges that he has referred to was in a subordinate capacity. Such experience, if properly harnessed, may satisfy the requirements of the I.R.C. Codes. But the evidence of the Witnesses, who have been examined reveals that Mr. Diwan did not supervise either the prestressing operations or the construction work. This is important. I do not suggest that Mr. Diwan should have remained physically present like a Junior Site Engineer. His status as Consulting Engineer requires him to oversee or supervise the work. As Consulting Engineer he was obliged to provide the intellectual guidance. He knew that no one at the site possessed the knowledge or experience expected by the I.R.C. Code. It is for this reason that Mr. Diwan's role assumes great importance. Mr. Desai, Mr. Palshetkar, Mr. Paranjape were no doubt present throughout the work of prestressing. Mr. Diwan (Con. W-1) visited the site, while the work of prestressing of first cable was going on. He admits in paragraph 81 of his testimony that he was not present when the remaining five cables were stressed. This means that the cables which were stressed on 17th September 1980, were

stressed without any supervision at all. The presence of Mr. Desai (M.W.-3), Mr. Palshetkar (M.W.-5) and Mr. Paranjape (Con. W-2) does not constitute supervision. Mansoori was a Fitter-foreman. He was experienced only in manual work.

94. In order to be effective, supervision has to be by men who know the job and who have experience of the work of prestressing. Supervision means overseeing or superintending execution of work. It pre-supposes possession of capacity, qualifications and experience of the kind of work that he is expected to supervise.

95. Since none of these Engineers possessed these qualities, they lacked capacity and competence to supervise. The "supervision" of prestressing of cables by these men is akin to a blind man leading another blind man. That left Mr. Diwan (Con. W-1). If Mr. Diwan (Con. W-1) was not present to supervise, I must hold that there was no supervision at all. If I hold that Mr. Diwan (Con. W-1) lacked competence and experience, then also there was no supervision.

(d) Mr. Diwan (Con. W-1)

96. Mr. Diwan claims to be the leader. Indeed he was. But did he possess the capability and confidence needed to carry the burden? I do not think that Mr. Diwan possesses the conviction and confidence expected of an Expert, who can supervise the prestressed concrete work of such magnitude. Mr. Joshi (Con. W-3) has in paragraph 9 of his testimony stated that Mr. Diwan (Con. W-1) met the Manager of Killick Nixon & Company to inquire about the criteria for stressing of wires. Now, if Mr. Diwan (Con. W-1) had such a vast experience of prestressing why was it necessary to go to the manufacturers of the jacking equipment for knowing the criteria? Mr. Joshi implies that the criteria of stressing wires were not known to Mr. Diwan (Con. W-1). Mr. Diwan (Con. W-1), a Consulting Engineer, was expected to know whether elongation of cables by itself is relevant or it should be considered along with the load applied. In this connection, the evidence of Mr. Diwan (Con. W-1) that the jacking equipment started leaking on 16th September 1980 assumes significance. In all probability, the jacking equipment was out of order and yet they were getting extensions of the cables. It must be in this connection that Mr. Diwan (Con. W-1) and Mr. Joshi (Con. W-3) went to the Manager of Killick Nixon & Co. The subject of their discussion betrays the confusion in Mr. Diwan's mind. This is what Mr. Joshi (Con. W-3) says :

"He (Manager) told us that we should go by the total elongation of the wires and not by the loads."

Now, therefore, Mr. Diwan was not sure whether elongation of wires has to be co-related to the load. It is legitimate to seek information of the equipment, its quality and operational details. But an expert like Mr. Diwan (Con. W-1) seeking information as to what are the criteria for prestressing cables betrays lack of confidence and perhaps absence of expert knowledge.

I will quote a few more instances which reveal that Mr. Diwan lacks the confidence of an Expert. Mr. Diwan (Con. W-1) has asserted that though he had prescribed the maximum load of 5.5 tonnes, the application of such load was out of question because the extensions designed by him must be obtained with the load of 4.2 tonnes. He was confronted with the record of extensions (Ex. M-16). He was driven to admit that in fact in the case of Wire Nos. 3 to 12 of Cable No. 10 a load of 5.5 tonnes was applied. If a load in excess of 4.8 tonnes would never be necessary and the designed extension must be obtained at 4.8 tonnes, why did he provide for a maximum load of 5.5 tonnes. No rational explanation is offered. His answer destroys his case that with the design which he made, every wire must get the designed extension at the load of 4.2 tonnes. He was persistently questioned on different aspects of his design. He almost gave up his claim of being an expert in prestressed work. I quote the question and his answer :

“ Q. In the case of Wire No. 1 of Cable No. 10 why was the higher load of 4.80, 5.20 and 5.50 tonnes not applied ?

A. *They were experienced people and had worked at Lalbaug site. It was their judgement and they had exercised it correctly.* The maximum load applied for restressing was 5.20 tonnes. The actual load applied has not been mentioned.” (Emphasis mine).

Having started with a claim of being a person of extensive experience in bridge building, finally Mr. Diwan (Con. W-1) threw the responsibility on the persons who worked at the site. It is these people whom he referred to as “they were experienced people”. In other words, Mr. Diwan (Con. W-1) relied upon the judgement of the fitter Mansoori and the labourers and abdicated his role as expert guide. I cannot, but, conclude that Mr. Diwan failed to display the qualities of an Expert. That is why finally he had to admit that he left the matter to the persons at the site.

Neither at Lalbaug nor at Byculla anyone for Killick Nixon & Company were present to supervise operations. Here again Mr. Diwan (Con. W-1) and the Contractors had to rely upon their fitter Mansoori, who had never done any work of prestressing concrete, except at Lalbaug.

Mr. Diwan (Con. W-1) admits that the jacking equipment was leaking. He says that it was repaired. Who repaired it? None from Killick Nixon & Company came at the site. The evidence does not reveal that anyone from the manufacturers were called to repair the jacking equipment. With such a leaking equipment how was the work of prestressing carried on? Mr. Paranjape's evidence is significant. In paragraph 24, Mr. Paranjape (Con. W-2) confirms that something was wrong with the jacking equipment. I quote his words :

“The work of prestressing had to be stopped because the operator of the jack found that he could not operate beyond the load of 4.50 tonnes.”

Mr. Diwan (Con. W-1) or the Contractors did not pause to stop the work in spite of the unsatisfactory performance of the jacking equipment. Instead, they went on recording the "extensions" irrespective of the working of the equipment. It is against this background of facts that I have to judge the quality of supervision of the prestressing operations.

(e) Supervision

97. In view of the above discussion of some aspects of the evidence, I conclude that the quality of supervision of the prestressing work was unsatisfactory. I give below the reasons :

(i) The work of prestressing was carried on under the supervision of Mr. Diwan, who has displayed lack of confidence required of an expert.

(ii) He was not present throughout the operations. His presence was necessary because none of the other Engineers at the site had any experience or qualifications necessary for prestressing work.

(iii) The jacking equipment was admittedly behaving in an unsatisfactory fashion. According to Mr. Diwan there was a leakage. According to Mr. Paranjape it would not work beyond certain limits. Yet the work was carried on.

(iv) In the absence of competent Engineers possessing the expertise expected by the I.R.C. Code, the work was left exclusively in the hands of a fitter by name Mansoori.

(v) The Engineers of the Corporation by reason of lack of qualifications and experience were not fit to supervise such work. This fact was known to Mr. Diwan. The fact that these Engineers were asked to work at the site is not of their making. They were employees and were bound to do what they were asked to do. Besides their role was different from that of the Contractors.

(vi) The unsatisfactory design factors have been stated earlier. Neither Mansoori nor the Site Engineer, Mr. Paranjape had the benefit of Mr. Diwan's continued presence and guidance.

On the whole, therefore, the supervision of the prestressing work was unsatisfactory rendering the actual work of prestressing unscientific and much below the standard laid down by I.R.C. Code.

(iv) The Cable Stressing Book

(a) Manner of keeping record

98. There is no record of Cable Stressing maintained by the Contractors, though Mr. Diwan says that he had asked them to maintain one. The only record available is Ex. M-16. It is a 100 pages notebook and is described as "Cable Stressing Register.". All the Engineers, who have given evidence have admitted that readings were recorded on loose sheets of paper. Mr. Desai (M.W.-3) and Mr. Palshetkar (M.W.-5) did not state that Mr. Paranjape (Con. W-2) also made a note of the extensions on a sheet of paper, but Mr. Paranjape (Con. W-2) claims to have done so.

The loose sheets of paper have not been preserved or produced. Mr. Diwan (Con. W-1), Mr. Umadi (M.W.-2), Mr. Joshi (Con. W-3), Mr. Palshetkar (M.W.-5) and Mr. Paranjape (Con. W-2) are unanimous in their word that the Cable Stressing Book is an important document. The method of recording the readings on the loose sheets of paper is not correct. The Register must contain entries made contemporaneously with the measurements. If this is not done and loose sheets of paper are used, it leaves scope for manipulations of readings and makes supervision difficult. Indeed this has been the result.

(b) Extension of wires

99. The Stressing of Cable No. 1 commenced from the North end. Wire Nos. 2, 3, 5, 6, 7, 9, 11 and 12 had to be stressed from the South end. The total of the extensions from the North and South ends made up the elongation of the cables as per the design. But I find that Wire No. 10 received elongation of 11.50 cms. at a load of 4.5 tonnes. No attempt was made to extend it further with 4.8 tonnes or 5.2 tonnes. In Cable No. 2 Wire Nos. 2, 4, 5, 6, 7, 8, 9, 10, 11 and 12 were all stressed from the opposite end at a load of 5.2 tonnes. In the case of Cable No. 10 the results were somewhat surprising. No wire received extension as designed even at the load of 5.5 tonnes. Wire No. 1 received elongation of 9.70 cms at 4.50 tonnes but was not stressed further at all. It had to be stressed from the opposite end to get the extension of 11 cms. The total extension was thus 20.70 cms. In this cable all the wires were stressed from the opposite end as none of them received extension at 5.50 tonnes. This situation was not designed by Mr. Diwan. There is a column which reads "restressing from North at 5.2 tonnes". This means that all the wires were subjected to a load of 5.2 tonnes. The same wire which received extension of 9.70 cms. with 4.5 tonnes from the South end received extension of 11 cms. at a lesser load. For instance Wire No. 4 received extension of 6 cms. at 5.5 tonnes from the South end. From the North end when a load of 5.2 tonnes was applied the extension was 14 cms. Wire No. 7 received extension of 7.50 cms. at 5.50 tonnes load. With a load of 5.2 tonnes from the opposite end it received extension of 12.50 cms. Similar phenomenon occurred in the case of other wires of Cable No. 10.

The record of Cable No. 9 reveals an interesting phenomenon. The stressing commenced from the North end. None of the wires received the designed extension of 5.2 tonnes. Therefore, all of them were stretched from the opposite end. The opposite end would be the South end. The column in regard to the stressing from the opposite end is designated "restressing from the North end". If the stretching commenced from the North end "restressing" ought to commence from the South end. This is said to be a mistake. In all probability, the Fitter or Foreman, Mansoori and the Site Engineers were asked by Mr. Diwan to ensure that the wires get the designed extensions. The requisite elongation may be a criterion for judging whether the stress was induced. But this has to be done by proper supervision. How is it that all the wires did not receive extension?

Why was it necessary to "restress" so many wires from the opposite end? What was the effect of the fault noticed in the jacking equipment? How is it that a wire which receives small extension, receives a higher extension from the opposite end with a lesser pull? I do not suggest that such behaviour by wires is not likely. There may be scientific reasons. But Mr. Diwan did not disclose any. These questions ought to have led Mr. Diwan into inquiry. Instead of pausing to inquire he left the matter to inexperienced persons. The fact that the record mentions "North" at both ends suggests that record was not kept carefully.

In the case of Cable No. 3 all but three wires received the extension at 5.50 tonnes. But here again the record shows that the stressing commenced from the South end and restressing also commenced from the "South end". This is claimed to be a second mistake in recording the direction from which restressing was done.

Cable No. 4 received extension at 5.20 tonnes and no wire had to be restressed.

These inconsistent "results" called for investigation. Mr. Diwan did not make any inquiry, but allowed the fitter foreman to go on with the work. The record Ex. M-16 does not inspire confidence. If a large number of wires did not receive extensions, it may mean that the prestress was not adequate. The Expert Panel was unable to find fault with prestressing as a cause of the collapse. They saw the cable stressing book (Ex. M-16) and accepted it as good evidence of elongation of cables. This was natural. But the oral evidence led before me has opened up a wide gulf between what was designed and what was actually done. The evidence before me has compelled me to probe into this aspect of actual work of prestressing. Consider two possibilities :

(i) The readings of restressing from opposite end are made up only to bring the total extension in conformity with the designed extension. The result is that the stress was inadequate.

(ii) The variations between recorded extensions are far in excess of permissible limits—the result is inadequate prestress.

If either of these two possibilities become real, the result is that there was inadequate stress induced in the concrete.

100. The Panel of Experts have clearly stated that they did not find anything wrong. At the stage when the Panel of Experts considered the Prestressing Operations, they had before them only one Register, the Cable Stressing Register (Ex. M-16). In the absence of any other evidence they naturally considered the Cable Stressing Register as good evidence of the quality of work. But the oral evidence recorded by me has introduced facts which call for a closer scrutiny of the quality of Prestressing Operations. The following facts were not before the Panel of Experts but they have been brought in the evidence recorded by me :

(i) The discrepancies in the record of extensions of wires.

(ii) The defect in the jacking equipment—particularly the leakage.

(iii) Absence of any reliable evidence that the jacking equipment was repaired before proceeding with the Prestressing Operations.

(iv) Absence of Mr. Diwan throughout the stressing of five out of the six cables.

It is for these reasons that I have proceeded to examine the Prestressing Operations. But if it is found that in all probability there was inadequate prestress because the record of prestress is unreliable or because the cables were not restressed from the opposite end as recorded, then the whole picture will change. The variations in the extensions have also to be borne in mind. As I will demonstrate presently the variations in the extensions of some wires are so great that a probability that adequate prestress was not induced cannot be excluded.

I should make one thing clear. When I set out to examine the value of the prestressing register and the quality of workmanship, I do not intend to impute dishonesty either to the Site Engineers or to the workmen like Mansoori and others employed by the Contractors. The Engineers of the Corporation as also Mr. Paranjape and Mansoori were ignorant about and inexperienced in the process of prestressing, which is a specialised job. Even Mr. Diwan (Con. W-1) and Mr. Joshi (Con. W-3) had to meet the Manager of Killick Nixon & Company to understand the criteria of prestressing. If I find that the quality of prestressing was poor or that the record is unreliable, it does not mean that they were not present at the site or that they deliberately fabricated the Cable Stressing Book. My conclusion in this Chapter are intended to evaluate the quality of supervision by Mr. Diwan. The other Engineers were incapable of supervising.

(c) Variations in Extensions

101. The following statement brings out the extent of variations in the elongation of the cables. The variations exceed the permissible limits not only in the first stressing but also in the record of restressing. It may be noticed that the percentage of variations between the variations of two wires is far in excessive of the permissible variation of 5 per cent :

| Wire No. | Original Stressing | Variations between two wires (Appendix 1) | Restressing | Variations between two wires (Appendix 1) |
|--------------------|--------------------|---|-------------|---|
| <i>Cable No. 1</i> | | | | |
| 2 | 18.70 | 8.3% | 1.80 | |
| 4 | 20.30 | | | |
| 5 | 18.50 | 14% | 2.50 | 50% |
| 6 | 15.80 | | | |
| 11 | 15.50 | 13% | 6.00 | 20% |
| 12 | 13.20 | | | |

| Wire No. | Original Stressing | Variations between two wires (Appendix 1) | Restressing | Variations between two wires (Appendix 1) |
|---------------------|--------------------|---|-------------|---|
| <i>Cable No. 10</i> | | | | |
| 1 | 9.70 | 24% | 11.00 | 35% |
| 2 | 12.75 | | 6.50 | |
| 3 | 12.50 | 48% | 7.50 | 50% |
| 4 | 6.00 | | 14.00 | |
| <i>Cable No. 9</i> | | | | |
| 1 | 17.10 | 23% | 3.60 | 50% |
| 2 | 13.00 | | 8.00 | |
| 3 | 16.70 | 25% | 3.90 | 40% |
| 4 | 13.10 | | 5.00 | |

The examination made by me is undoubtedly at random. But the variations in the elongations of the pairs of cables leave no doubt that they exceed the permissible variations. I have taken the record of original stressing and restressing separately so that the extent of variation at both the stages is clearly understood. Dr. Gupchup's evidence leaves no doubt that excessive variations means inadequate prestress. I do not venture to conclude that the girder collapsed because of defective prestress. It is, however, safe to conclude that the work of prestressing was not scientific and in all probability the designed stresses were not induced.

(d) Cable Stressing Register

102. The Cable Stressing Register is an important document. It is the only document which keeps the record of extensions of wires. It is needless to emphasize that this record ought to be kept in a careful manner. The Cable Stressing Register (Ex. M-16) is not a document which ought to be taken at its face value. This is so for the following reasons :

(i) The original extensions recorded on sheets of paper have not been preserved and produced. Therefore, the readings in Ex. M-16 are not contemporaneous record of what happened at site.

(ii) Wires which did not receive extension of 6 cms. on the first stressing with the maximum load are shown to have received twice the extension with lesser load. No explanation about this has come forth.

(iii) In respect of two cables restressing is shown to have been done from the same end.

(iv) The circumstances under which relatively longer extensions were received with lesser loads have not been explained by Mr. Diwan.

(v) All the wires in Cable No. 9 had to be "restressed" from the opposite end. This, too, has not been explained satisfactorily.

(vi) The jacking equipment was certainly not working properly.

(vii) A look at the register suggests that additions of a few cms. have been made as "extensions" on restressing to bring the total near the designed extension.

(viii) The two "mistakes" in writing the directions from which the wires were stressed, are not natural.

(v) Conclusion on Prestressing

103. The cumulative effect of all these facts has to be taken into account. There are too many factors calling for explanation. The absence of Mr. Diwan throughout, the damage to the jacking equipment, restressing from the same end and restressing of all the wires are some of these circumstances which taken collectively suggest these inferences :

(i) Ex. M-16 was made up to reflect the figures which are near the designed extension.

(ii) The jacking equipment by reason of damage did not work properly and wrong results were obtained.

(iii) The variation between extensions are far in excess of the permissible limits.

(iv) The cables did not receive the designed extension and in all probability the designed stress was not induced.

(v) Stressing of cables was not satisfactory.

PART III—Concluded

PART IV

THE CAUSE OF THE COLLAPSE

I. EXPERT WITNESSES—PRINCIPLES OF EVALUATION OF EVIDENCE

104. As a general rule, opinions of witnesses are not admissible in evidence. Witnesses are to state the facts only. But Tribunals or Courts will not be in a position to form a correct judgement in cases which involve subjects beyond the range of common knowledge. Thus cases involving subjects like Medicine, Engineering, Chemistry, Arts and so on cannot be dealt with by Courts without the help of Experts. In such cases, the general rule against admissibility of opinion is relaxed. Indian Evidence Act (section 45) makes opinions on subjects like scientific knowledge admissible. This rule is founded on necessity.

105. An expert is a person possessing superior knowledge and practical experience in a particular branch of learning.

The Panel of Experts consists of Dr. Gupchup, Dr. Bondre and Mr. Gandhi. Their report is at Exhibit C-6. Among the witnesses, Dr. Gupchup (C. W-1) represents the opinion of the Panel. Mr. Diwan (Con. W-1) too is an expert. Thus I have before me the opinions of two distinguished Engineers. Dr. Gupchup (C. W-1) and two other members of the Panel hold that the crib stool system was overstressed. Damaged sleepers were used. In the result, the three timber sleepers were crushed. The Girder No. 1, therefore, tilted along its axis at the southern end. Therefore, the Girder No. 1 collapsed, bringing with it the Girder No. 2.

Mr. Diwan (Con. W-1) has two different theories—one for the tilt and another for the collapse. The tilt was caused as a result of the earthquake on 25th September 1980 which had its epicentre in Koyana. The girder was stable as the tilt was arrested at 20 mm. But in the early hours of 30th September 1980 the Girder No. 2 struck the Girder No. 1 horizontally and thereby caused collapse of the two girders.

106. Two learned Engineers have propounded divergent theories. I have to judge as to which one of them is acceptable. This cannot be done without evaluating the merits of the respective testimonies of Dr. Gupchup and Mr. Diwan. This means that I will have to find out which of the two experts is credible in so far as the theory propounded by him is concerned. It is here that the need to evaluate their oral testimony arises. This will have to be done on the basis of principles of law. Certain principles can be deduced from authoritative commentaries on law. The following principles are relevant :

(a) Experts generally speak not to facts but to opinions. It is often surprising to see with what facility and to what extent their views can be

made to correspond with the wishes and interests of the parties who call them. They do not wilfully misrepresent what they think but their judgement may become biased in favour of their own theory. The court ought to bear this in mind and such evidence which displays warped judgement should be rejected.⁹

(b) The expert evidence consists of opinion based on assumption of facts. While their evidence is necessary because the subject is beyond common knowledge, it must be ascertained that the assumption on which the evidence is based are well founded.¹⁰

(c) The Expert is fallible like all other witnesses and the real value of his evidence consists in the logical inference which he draws from what he has himself observed and does not resort to surmises.¹¹

(d) In assessing the relative value of the testimony of expert witnesses as compared with witnesses of fact, their demeanour, their type, their personality and the impression made by them upon the judge is important. For example it should be seen whether they confine themselves to giving evidence or act as advocate.¹²

(e) A Court or Tribunal ought to ensure that the expert giving scientific evidence does not play upon the ignorance of those who hear the evidence and that the evidence and the theories are not opposed to common sense.¹³

(f) In cases where the testimony does not relate to precise scientific facts or to the necessary conclusions which result from facts stated, but is speculative and theoretical in its nature, it should be received with caution.¹⁴

(g) The evidence of expert witness has to be appreciated like that of any other witness for even expert witnesses are liable to make mistakes. The opinion of expert is not conclusive. The opinion is nevertheless a valuable aid in arriving at the right decision. The value of an opinion given by an expert depends upon the material put before him. An opinion divorced from facts is not an opinion but a wild conjecture. Therefore, where the expert gives no data in support of his opinion, the opinion should be rejected.¹⁵

107. I will bear in mind these principles in evaluating the evidence of Dr. Gupchup and Mr. Diwan.

⁹ Sarkar on Evidence—Twelfth Edition, page 517.

¹⁰ *Ibid.*

¹¹ *Ibid.* page 518.

¹² Antonio Dias vs. Frederick Augustus Gray (A.I.R., 1936, P.C. 154).

¹³ Sarkar on Evidence—Twelfth Edition, page 518.

¹⁴ *Ibid.*

¹⁵ Pribhu Diyal vs. Secretary of State (A.I.R., 1931, Lahore, 364.)

II. EVALUATION OF EVIDENCE

(A) Need to evaluate

108. The divergent opinions given by Mr. Diwan on the one hand and the Panel of Experts on the other have to be examined on the basis of the credibility of their respective versions. The credibility of the opinion cannot be divorced from the credibility of the witness himself. For instance, if the approach of a witness is irrational and unscientific the value of his evidence, and, therefore, of his opinion is diminished. Similarly, bias or interest in favour of a particular opinion adversely affects the value of the evidence. Thirdly, lack of expert knowledge nearly destroys the value of such opinion. I have divided the consideration of the evidence as to the two opinions into two parts :

- (i) General credibility of the two experts who have given evidence. (Paragraphs 109-134 below.)
- (ii) Testing of the opinions on the basis of acceptable evidence. (Paragraph 135 below.)

I will first examine the general credibility of Mr. Diwan (Con. W-1) and Dr. Gupchup (C. W-1).

(B) General Credibility

(i) MR. DIWAN (CON. W-1)

(a) *Bias*

109. A person who gives evidence on scientific or technical matter must be unbiased. The personality of Mr. Diwan and his relationship with the contractors have to be borne in mind, in judging the existence of bias. I do not suggest that his association with the contractors as a Consultant by itself reduces the trustworthiness of his opinion. Far from it. But it calls for caution. Mr. Diwan (Con. W-1) is not an independent consultant of the kind one finds in day-to-day experience. He, too, makes no secret of it. He confesses that he involved himself with the execution of the work. A Consultant whose personality is not independent of his client lacks objectivity and detachment. By the very nature of his contract with Messrs. Model Construction Company, Mr. Diwan (Con. W-1) is incapable of showing such detachment. Look at his contract with Messrs. Model Construction Company (Ex. Con-8). The contract came into force on 1st December 1976. The notice inviting tenders for the Byculla and Lalbaug projects was published on 28th October 1976. The last date for filing tenders was 15th December 1976. There is, no doubt, that this contract was entered into for the purpose of the projects of Byculla and Lalbaug. Thus, Mr. Diwan (Con. W-1) was appointed for the purpose of these very projects. The Contract obliges Mr. Diwan (Con. W-1) to do the following acts :

- (i) To act as Construction Consultant with executive directions.
- (ii) Prepare the tenders and render assistance and guidance for execution of the work awarded.

(iii) He cannot accept work where there is conflict of interest with the contractors.

Thus, he had to design and execute the work. In view of his involvement with the execution he was not an independent Consultant.

110. The terms in regard to his remuneration are of significance. He was not to share any losses and was to receive 2 per cent of the gross value of the work executed as his professional fees. In other words, he had a 2 per cent. share in the gross value. Besides, he was to receive Rs. 2,500 per month as retainership which was to be chargeable to the work and was not to be adjusted against the professional fees of 2 per cent. He was not to receive fees for the preparation of tenders. The terms as to remuneration suggest that the position of Mr. Diwan was not different from a Partner of the firm, the only qualification being that his "partnership" extended to the works assigned to him. Partnership is an association of persons for the purpose of sharing profits. Mr. Diwan's relationship is similar to that of a partner.

Clause 9 of the Contract entitles Mr. Diwan (Con. W-1) to become a partner after two years. As such partner he would share :

" 30 per cent (thirty per cent) of the nett profits *in lieu of* professional fees of 2 per cent mentioned above."

The use of the words *in lieu of* suggest that 2 per cent share he now received would be replaced by a requisite share in the profits. The contract establishes beyond any doubt that Mr. Diwan (Con. W-1) is a part and parcel of the organisation of Contractors though he has styled himself as Consulting Engineer of the Contractors. This is the first factor which suggests an interest in the Contractor's success in the project. I will consider whether this interest became so strong as to amount bias.

Mr. Diwan's (Con. W-1) evidence reveals that the only projects currently held by him were the Lalbaug and Byculla Projects. He has not stated that he has any other work as an independent Consultant with any other party. This means that the only source of income disclosed by evidence is the income received from the Contractors. In such circumstances, is it likely that Mr. Diwan's opinion would be disinterested ?

111. Now consider his evidence. The centering system designed and executed by him was criticised by the Panel and he was questioned about it. While he admitted that all the timber ballies used for centering system were not straight and erect, he hastened to qualify the statement by saying that all except a few were erect and straight. I have already demonstrated that only 30 per cent of the ballies were straight and erect. Mr. Diwan (Con. W-1) has displayed such keen interest in upholding the soundness of his system that he refused to accept the facts which were found at the site. He, himself, makes no secret of his attachment to the Contractors. He has repeatedly referred to him and the Contractors by the word "we". His conduct in going with the contractors on the night of the tilt to Shenoy and

Company for securing cribs is not the conduct of independent disinterested Consultant. He is one with the Contractors. An independent Consultant would direct his Contractors to keep the requisite material at site so that he could supervise the work as and when required. Instead he based his design on the material the Contractors were able to procure. He spoke for the Contractors when he said that the cribs could not be kept ready as the "money position was tight". This should have legitimately come from the Contractors. I have no doubt, that Mr. Diwan is not independent Consultant but he is so deeply involved with the Contractors that he has lost his personality as an independent Consulting Engineer. This is the background of his interestedness.

(b) *Rational and Scientific Approach*

112. In paragraphs 69, 72, 87, 88, 89, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102 and 103, I have dealt with the unscientific nature of the work. The facts stated in those paragraphs should be borne in mind.

113. His failure to insist upon the timber ballies and bamboo bracings as designed by him is another unscientific practice followed by him. He has compromised his own design. Yet at page 151 he asserts that the centering work was according to his design.

114. At page 161 of his evidence, he has asserted that the guidelines produced by him advocate the composite system of centering as designed by him. A search for such advocacy in the guidelines would reveal that there is no such statement in the guidelines.

Paragraph 47 of his evidence reveals one more aspect of the not too rational a way of thinking. Horizontal bracings in the centering system are provided to enable the system to resist the horizontal forces. But Mr. Diwan has an unusual approach. According to him he designed the horizontal bracings not for the purpose of resisting the horizontal forces but for the purpose of *reducing the slenderness ratio of the vertical props*. It is not clear how the slenderness ratio of the vertical props is reduced by bracings. The ratio depends upon the height of the Bally to its width.

115. In paragraph 82 he tried to explain away that in the case of Wire No. 1 the designed extension was not obtained at 5.2 tonnes and, therefore, the further load was not applied. For this reason, higher loads were not applied to Wire No. 2, but then he immediately admits that the problem in regard to Wire No. 2 did not arise in his presence. Various discrepancies in extensions were brought to his notice. But there is only one answer that he was right. Mr. Diwan tends to be irrational and arbitrary.

116. A huge girder weighing 72 tonnes had tilted thereby creating an alarming situation at the site. But Mr. Diwan continues to assert that everything was safe and there was no need to take any emergency measures. This is again irrational because anyone with common sense would be struck by the magnitude of the possible disaster. It is because of the innate bias in

favour of the Contractors that Dr. Diwan continued to assert that there was nothing that should cause fear. But his opinion is contrary to his behaviour. On the night of the occurrence of the tilt at 11 p.m. he accompanied the Contractors partners to the house of Kudal and the factory of Shenoy and Company to secure steel cribs for erecting towers. The visit to the factory around midnight was not a courtesy visit. No reasonable person would rush like this, unless there was emergency. Lastly, look at paragraph 97 of his testimony. According to him, there is no limit for variations of two wires in a cable. In other words one wire may receive extension of 2 cms. and the next wire may receive extension of 13 cms. This according to Mr. Diwan is permissible. I am afraid, this has to be rejected as altogether irrational and unscientific. Variations must remain within reasonable limits with reference to the design; otherwise, the cable does not receive the designed stress. Indeed, if Mr. Diwan is right, there is no need to design the extension of wires. His attention was drawn to page 598 of the well-known book "Design of Prestressed Concrete Structures" by T. Y. Lin, 2nd Edition, where it is stated the cause of any discrepancy exceeding 5 per cent shall be ascertained and corrected. But Mr. Diwan disagrees with T. Y. Lin without stating any reasons. His disagreement, in my opinion, is irrational and arbitrary. Having regard to the totality of these facts, Mr. Diwan has displayed a tendency to be irrational and unscientific.

(c) Knowledge of the Subject

117. Prestressing force is determined by measuring tendon elongation and also by checking jack pressure on a calibrated gage. This is clear from page 598 of T. Y. Lin's book. But Mr. Diwan disagrees with him. He went with Mr. Joshi to the Manager of Killick Nixon and Company for ascertaining whether prestressing forces is determined by measuring tendon elongation or by checking jacking pressure. The textbook lays down that prestressing force is determined by :

- (a) measuring elongation ; and
- (b) checking jack pressure.

But Mr. Diwan—an expert on prestressed concrete girder bridge—had to go to the manufacturers to educate himself on this aspect. I am afraid, Mr. Diwan does not possess expert knowledge of prestressed work.

118. According to him Bamboo is timber. Bamboo is hollow from within. Timber is a species of wood. A look at the dictionary meanings of these words would point out the difference between the two. But Mr. Diwan (Con. W-1) does not know this fact and proceeds to use bamboo bracings by means of nails. This speaks about his knowledge about the use of such material.

119. Now the process of "hogging". It is common knowledge for Engineers that hogging is a natural process in prestressed girders. Mr. Diwan

asserts that *in the first stage of prestressing there is no hogging*. But immediately admits that *it is the central portion of the girder that undergoes perceptible change as a result of hogging*.

In paragraph 96 he made this statement :

“I agree that the phenomenon of hogging does take place at the first stage of stressing but for the reasons already stated the load does not shift to the southern angles of the temporary system.”

By such inconsistent statements, he has discredited himself as an Engineer.

120. He has come out with a proposition that in order to judge the stress induced in the girder the average extension of all the six cables has to be taken into account. According to him, therefore, even if one cable is not stressed and the remaining five cables are overstressed and if the average of the extensions of all the six cables conforms to the designed extensions, the girder should be taken to have been adequately stressed. This is not a scientifically valid statement. The average of all the cables is valid for the midspan, but not for the ends of the girders. Initially, he attempted to play upon the ignorance of advocates and the Commission by calling attention to the design calculations. But he was told that pages 21-22 of Ex. Con-6 (Design Calculations) relate to the midspan. He then realised that he was wrong. He was driven to admit his mistake. He then modified his earlier view by conceding that unless all the cables are fully or partially stressed, his opinion would not be valid.

121. The various factors connected with the prestressed work have already been stated by me. For instance, the failure to take two slips into account when admittedly stressing was to be done from both the ends is a fact which disclosed lack of capacity and expert knowledge as a designer.

122. Then his ignorance about the existence of any book on Prestressing by Indian authors. If Mr. Diwan (Con. W-1) is such an experienced Consulting Engineer, he ought to have known that there is at least one book by an Indian author. He does not accept the authority of T. Y. Lin and he is not aware of the existence of any Indian Book. I have myself come across a book titled “Prestressed Concrete” by an Indian author by name Mr. A. T. Nebharajani published by D. B. Taraporewala and Company Private Limited, Bombay. I do not see how Mr. Diwan can be accepted as Expert on Prestressed Girder Bridges.

123. This is the summary of the knowledgibility of Mr. Diwan on the subject on which he has come forward to give evidence. I am afraid, this background of his knowledge does not make him credible as an Expert witness.

(ii) DR. GUPCHUP (C. W-1)

(a) Background

124. It is unnecessary to repeat the academic distinctions of Dr. Gupchup. His eminence as an Engineer is well-known. His evidence represents the

version as to the cause given by the three experts who constituted the Panel. Opinions expressed by Dr. Gupchup and the report proved by him should be taken as the collective opinion of the Panel. The report is not the product of the intelligence and experience of Dr. Gupchup alone. The thinking, the experience and the intelligence of Dr. Bondre and Mr. Gandhi also have gone into the making of the report. This should be borne in mind. Counsel for the Corporation, was somewhat unfair to Dr. Gupchup, when he secured an answer that Dr. Gupchup had not designed any bridges. He ought to have asked further questions and enquired whether any one of the three Experts has designed bridges. That would have completed the matter. Dr. Bondre has designed numerous bridges, which fact is clear from the evidence of Dr. Gupchup, as also from Appendix 'D' to this report.

I will now proceed to examine the evidence of Dr. Gupchup with reference to the existence of bias, rational and scientific approach and the knowledge of the subject.

(b) Bias

125. The opinion of Dr. Gupchup is based on facts supplied to him by the Commission. The Panel visited the site and analysed the materials used in construction. The Panel has been generally fair to the contractors inasmuch as they have frankly conceded that nothing was found wrong with the steel cribs, cables and the concrete. They did not comment upon whether the methods employed were scientific. A closer scrutiny would have revealed the unscientific methods used. They refrained from travelling beyond the subject of inquiry. Dr. Gupchup displayed fairness in the inquiry made by him, as to the effect of the earthquakes. In the manner in which Dr. Gupchup and the Panel proceeded, a totally scientific and logical procedure was adopted. No assumption was made and no conjectures were resorted to. Wherever a conjecture had to be made, they fairly conceded it. Dr. Gupchup, as also the two other members, are totally unbiased and disinterested in the result of the inquiry. As I will demonstrate, Dr. Gupchup has been extremely objective and detached in his testimony. Indeed, in the cross-examination not even a suggestion of bias has been made.

126. In the investigation about the temporary supporting system, Dr. Gupchup was asked as to why he had to go into the question of desirability of the centering system. In the first place, the question of the cross-examiner ignored that a logical investigation called for inquiry into all aspects of the construction. Investigation into centering system as into other aspects, was necessary to eliminate defective centering as a cause of the collapse. The very first probable cause to any Engineering mind would be the supporting system. Attention to the quality of centering system was natural because the girders collapsed when one of them was standing on the centering system. Dr. Gupchup would not have gone into the question of the desirability of the centering system, but for the fact that the adjacent R.C.C. span which stood on timber ballies disclosed use of spliced ballies below the span. It is for this reason that they proceeded on the assumption

of use of spliced ballies below the Girder No. 2. In my opinion, this was a logical step that reveals a trained analytical mind. Even so, Dr. Gupchup has fairly conceded that the system, though undesirable, is not forbidden by any Code or practice.

127. The next aspect of his evidence which reveals fairness to the designer and, therefore, lack of bias, is this. The question of stability of the centering system was asked. He fairly conceded that the horizontal load of 10 per cent. would be counteracted by the vertical load of 72 tonnes by reason of the friction. No fault was found with the design of the centering and indeed Dr. Gupchup said that the design was adequate.

128. Dr. Gupchup and the other members did not travel beyond the scope of the inquiry entrusted to them. That is why, though they discussed the distances at which the girders had fallen, they did not venture to investigate its causes, which were for the first time disclosed in his evidence. Had Counsel not asked, he would not have stated the cause.

Dr. Gupchup then did not hesitate to concede that the damage to the timber ballies and sleepers lying at the site could have been caused because of the unprotected exposure for a few months. This again displays willingness to give a fair account of the facts. Then in paragraph 33, he accepted the Contractors' version that the tilt was stabilized by reason of the packings given. No attempt was made to take sides. Every fact in favour of the Contractors was conceded. All these facts unmistakably point to a total absence of bias on the part of Dr. Gupchup and members of the Panel.

(c) Rational-Scientific Approach

129. Neither the Corporation's Advocate nor the Contractors' Advocate have been able to find fault with the absolutely scientific and rational approach adopted by the panel of experts. Indeed, the evidence is replete with instances which show rational and scientific approach to the questions considered by the Panel. I will cite a few.

130. Dr. Gupchup was questioned about the reasons for the conclusion that the tilt of the girder must have increased before the collapse. He has given three good reasons. Secondly, he was questioned about the meaning of the words "distress" and "over-stress", and the calculations therefor. His statement that "distress" being an observed phenomenon does not require calculation was not even challenged. About "over-stress", he has drawn attention to the calculations in the report. Similarly, he has given rational answer to the question as to which members in the temporary crib stool system underwent higher stress. Numerous questions about the conditions under which failure would be caused were asked and each of the questions has been answered with scientific accuracy.

131. In paragraph 36, he called attention to the fact that the calculations shown to the Panel revealed that there were only four props in the crib

stool system, each of the diameter of $2\frac{1}{2}$ inches, whereas in the drawings furnished to them eight props were shown and the diameter was not shown. This discloses the meticulous attention to details and strictly scientific approach to the problems and a refusal to make any assumptions. He was then asked to give reasons for the conclusion that the diagonal flats of the crib would hardly take any load. His answer was that the crib was supported at the bottom by the timber sleepers, and the force of the load being vertical, The vertical angles would take the load directly. This is entirely scientific and logical and no fault could be found with this method of thinking. There are numerous such questions which have been answered with ease and effortlessness disclosing a total control over the facts known to him and the confidence in his capacity as an expert.

He was then questioned about the validity of his claim that Girder No. 1 collapsed first. Here again, the process of thinking is so rational that it is difficult to doubt his general credibility as an expert. Girder No. 2 withstood considerable stress for seven days. A girder which stood for seven days without any sign of distress would continue to stand on the centering. Therefore, Girder No. 2 would not fall unless there was a cause. Since no such cause was discernible, the probability that Girder No. 2 fell first was eliminated—entirely logical conclusion. That left the Girder No. 1. The cause of its collapse is considered separately. This process of elimination adopted by the experts is consistent with the scientific way of thinking. An attempt was made in paragraph 39 to create a contradiction between his evidence and the report. According to Dr. Gupchup, the fall of the first girder caused vibrations, thereby disturbing the centering system of the second girder. It is this impact that brought down the second girder. He clarified that in the report it is not stated that the impact of the first girder caused the collapse of Girder No. 2. Later on, in reply to my question, he has made it amply clear that Girder No. 2 was brought down by the impact—not of Girder No. 1 itself but of its fall. I see no difficulty in accepting the amplification made by Dr. Gupchup.

132. Dr. Gupchup has not ventured to assert that his opinion in regard to the earthquake is infallible. Indeed, he has accepted that with the knowledge of ground acceleration in Bombay region a better conclusion would have been reached. Admittedly, such evidence was impossible to secure.

133. The evidence of Dr. Gupchup reveals that he has an absolutely scientific and analytical mind, which inspires confidence in the quality of the investigations made by him and the opinion expressed. In the witness-box he showed great mental poise, dignity and respect for Mr. Diwan's right to hold a contrary opinion.

(iii) *Conclusions*

134. The evaluation made by me of the relative merits of the testimony of Mr. Diwan (Con. W-1) and Dr. Gupchup (C. W-1) compels me to

conclude that Dr. Gupchup's (C. W-1) evidence possesses a high order of credibility. He has demonstrated a total lack of bias in favour of any particular opinion, willingness to correct when mistakes were pointed out, readiness to make fair concessions when deserved and sound knowledge of the subject on which he gave opinion. In judicial decisions, weighing of oral evidence is of utmost importance. The choice of one of the two versions is not free from difficulties. But both the witnesses were clear and lucid in their expression. There was good searching cross-examination. This offered immense opportunity to analyse critically on the basis of well established principles, the testimonies of the two witnesses. Perfection in scientific knowledge, as in other branches, is not expected of any person. But Mr. Diwan has betrayed complete bias in his views. There is absence of rational approach to the facts and their interpretation. On the question of knowledge of the subject also, Mr. Diwan's (Con. W-1) testimony does not inspire confidence. The conclusion is that Dr. Gupchup's evidence is far too superior in its quality to that of Mr. Diwan.

III. CAUSE OF COLLAPSE—DIVERGENT THEORIES

(i) MR. DIWAN'S OPINION

135. Mr. Diwan holds a view that the cause of the tilt of Girder No. 1 at the southern end and the cause of the collapse of the two girders are different. I will, therefore, consider his opinion under separate heads.

(a) *The cause of the tilt*

136. Mr. Diwan's opinion¹⁸ may be summarised as follows :

(a) There was an earthquake on 25th September 1980 of the magnitude of II in Modified Mercalli Scale of Intensity. Horizontal Forces released by earthquakes act as vibrations. They impinged upon the Crib Stool System at the southern portal frame. These vibrations are not uniform in their intensity at any two consecutive points. Their graph consists the series of crests and troughs like waves. They take the form of sine curve (~~)

(b) Two or more such waves of earthquake vibrations "may" act in such manner as to multiply their effect. As a result of such multiplication of the intensity of the waves up and down movements of the girder are caused. If these movements of the girder coincide with the position of the waves, it results in resonance, causing momentary stress. There is *one in a million chance* of such multiplied intensity. The combination of the stress caused by this "chance" together with the stress caused by vibrations of traffic acts in a concentrated way. This "may" cause cracks in the timber sleepers.

(c) The vibrations caused by earthquakes having epicentre in Koyna travelled to Bombay. Their direction "may" be in the direction of the

¹⁸Paragraphs 49-50 of Mr. Diwan's evidence.

diagonals of the Steel cribs, on the portal frame. Therefore, the concentrated stress referred to above acted on the north-west corner of the western end panel of the crib on the southern portal. This "must" have acted on the wooden sleepers below the north western angle of the western panel of the crib. This caused the cracks in the timber sleepers and the resultant tilt of the girder at the southern end.

*(b) Cause of the Collapse*¹⁷

137. Mr. Diwan's opinion may be summarised as follows :

(a) Exhibit Con-7 contains two diagrams drawn by Mr. Diwan. One brings out the position of the fallen girders with reference to their original position on the portal frames. The second drawing illustrates Mr. Diwan's opinion about the cause of the collapse of the two girders.

(b) The Girder No. 1 did not fall first, but the Girder No. 2 fell first in the circumstances stated hereinafter.

(c) The top flange of Girder No. 1 fell towards the west. The top flange of Girder No. 2 fell towards the east.

(d) The distance at the south end between the position of Girder No. 1 on the portal frame and its position after fall is 15'. On the north side the same distance is 5'. The Girder No. 1 must have fallen at a velocity of 5.38' per second calculated at the centre. At the south end this velocity was 10.76' per second. The Girder No. 1 would collapse with such velocity if a correspondingly strong impact was made from the eastern side. This is possible if the Girder No. 2 struck the Girder No. 1 from the eastern side. This can happen if the Girder No. 2 fell along the arc with a radius measured from the bottom of the timber ballies. The Girder No. 2 fell giving such an impact at the southern end of Girder No. 1. In this process, the Girder No. 2 by its impact with Girder No. 1 received a spin or rebound in the opposite direction. That is why, the Girder No. 2 fell with its top flange facing towards the east.

(e) If girder No. 1 were to fall first, by itself, it would fall near the portal frame and not 15' away. If the Girder No. 2 were to fall after Girder No. 1, it would fall with its top flange facing towards the west.

(f) The cause of the collapse of Girder No. 2 is this :

"If" wedges below the timber ballies in the western row of the centering system of Girder No. 2 were removed or tampered with, it would disturb the centering system and the Girder No. 2 would fall along the arc towards west. Therefore the wedges from the western row of the timber ballies "must" have been removed thereby causing the collapse of Girder No. 2 which struck the eastern edge of Girder No. 1.

¹⁷Paragraph 51 of Mr. Diwan's evidence.

(ii) THE OPINION OF THE PANEL¹⁸—DR. GUPCHUP (C.W.-1)

(a) *Cause of the Tilt*

138. The Panel of Experts attributes the collapse of the two girders to the tilt and to the overstressed condition of the Crib Stool System. The cause of the collapse of the two girders is summarised below :

(a) The diagram showing the Crib Stool System is in paragraph 41 of this Report. The design calculations do not show the study of stresses developed in the timber sleepers.

(b) The calculations for load bearing capacity of Steel Cribs made by the designer are not rational. The reason is that the allowable stress in compression in Crib angles is computed and the same is assumed to be valid for diagonal flats. This is not correct.

(c) Modulus of elasticity of timber is less than that of Steel. Therefore, there will be smaller stress in timber sleepers. Thus timber props and flats will share lesser load. The Crib angles will share higher stress. Process of hogging will cause more load on the southern angles of the Crib Stool system. These angles will be subjected to higher stresses.

(d) The bearing stress in timber sleepers will depend upon how much dispersion was caused through the bottom angles. The bearing stress would be of the order of 213 kg./cm^2 [$9,000 + (6.5 \times 6.5)$]. This stress to which angles were subjected is high. This is confirmed by actual crushing of the sleepers.

Alternatively, the sleepers which were crushed were defective and, therefore, unable to stand the higher stresses.

(b) *Cause of the Collapse*

(a) The Girder No. 1 at its southern end tilted westwards. But additional packing of the gaps and propping was done on the eastern side as also on the west. The props and packing on the eastern side aggravated the condition of the tilted girder.

(b) The Crib Stool System which was overstressed was not relieved of the load of the girder for four days. The system with the sleepers in a highly stressed condition was left to carry the load of the girder. The highly stressed condition of the sleepers which were damaged formed the weak link in the whole system. The overstressed and weakened system, therefore, gave way. This caused the fall of the Girder No. 1.

(c) The Girder No. 1 fell down on the ground. The impact of this collapse caused vibration which disturbed the centering of the Girder No. 2. Therefore, the Girder No. 2 also fell after the Girder No. 1.

¹⁸ Report—Ex. C-6.

(iii) VALIDITY OF MR. DIWAN'S OPINION

(a) *The Tilt*

(a1) *Effect of the earthquake*

139. The earthquake which occurred on 25th September 1980 had Richter magnitude of 4.9 in Koyna Region. The cause of the earthquake, the mode in which vibrations travel and the successive diminution of intensity should be understood. Earthquakes are caused when rock masses on each side of the fault try to slip away from each other. When they slip away considerable energy is released. This causes earthquakes which are shock waves. The intensity diminishes with the distance from epicentre.¹⁹ Therefore, the intensity with which the surface of the earth at any point is shaken depends upon the magnitude of the shock and the distance.²⁰

140. For magnitudes less than 5 (Richter) the ground motion is unlikely to be damaging because of its very short duration and moderate acceleration.²¹

In the same article Table 4-3 shows that duration of the phase of shaking at Richter magnitude 5 is two seconds. The magnitude in Bombay was negligible. Therefore, duration and the shock was too inconsequential. This is relevant for considering the proposition of Mr. Diwan (Con. W-1) about the repeated impact of waves and the "one in a million chance" of resonance.

The intensity of the ground motion in Bombay is naturally not known. The intensity of the earthquakes in terms of Modified Mercalli Scale as understood from the letter of the Director-General of Meteorology is II. On the basis of this information let me now find out the damage-causing potential of the earthquake, by the method of logical deductions.

For design criteria for permanent structures, Bombay Region is associated with Modified Mercalli Scale of VII. Now on the basis of the design criteria for permanent structures the horizontal forces acting on the permanent structures are estimated to be 6 per cent of the vertical loads acting horizontally. This 6 per cent of horizontal load is calculated on the basis of Modified Mercalli Scale magnitude of VII. Now consider the existence of Earthquake shocks of the Magnitude II. The horizontal forces acting on a permanent structure with the magnitude of II would be much less than the 6 per cent applicable to the magnitude VII. It stands to reason, therefore, that the Earthquake forces acting at Bombay would be negligible. This conclusion flows from the logical deduction drawn from the scientific data furnished to me by the evidence of Dr. Gupchup. Now Mr. Diwan (Con. W-1) is the author of the Earthquake theory. What is the scientific or factual data in his

¹⁹ Paragraph 15 of the evidence of Dr. Gupchup (C W-1).

²⁰ Shock and Vibrations Handbook—Edited by Cyril M. Harris and Charles E. Crede, Volume III.

²¹ "Strong Ground Motion", Article by G.W. Housner California, published as Chapter IV in Earthquake Engineering, edited by Robert L. Viegel, p. 76.

possession? All that he has is the letter from the Director-General of Meteorology certifying that the magnitude was II. In the cross-examination of Dr. Gupchup (C. W.-1) the correctness of the deduction made by him has not even been questioned. Learned counsel for the Contractors harped upon the fact that the exact calculations about the ground acceleration could not be known in terms of Richter magnitude. Dr. Gupchup has conceded that a better conclusion was possible if the intensity of ground motions in Bombay was available. But this concession does not discredit his conclusion based on deductions from scientific facts. That a better conclusion was possible does not mean that what is now available is not good. Then a hypothetical question was asked in paragraph 42 as to whether in the absence of data about ground acceleration earthquake as a cause of the tilt cannot be ruled out. Naturally, Dr. Gupchup answered in the affirmative. Theoretically, earthquake cannot be ruled out. But facts about the ground motion have to be established. In the absence of such facts the hypothetical question is a mere shot in the dark. But I am required to find out the cause of the collapse. Like all Courts and Tribunals I am in duty bound to consider evidence of facts and not imaginary hypotheses. What are the facts?

(i) Earthquake Magnitude M.M.S. II.

(ii) Having regard to design criteria the effect of earthquake of Magnitude II is negligible.

Except suggesting the theoretical proposition that earthquake would have caused it, nothing more has been produced by Mr. Diwan. But the evidence of the magnitude of II and certain other propositions destroys Mr. Diwan's theory. In the Article *Strong ground motion* by G. W. Housner referred to earlier, it is stated that for magnitudes less than 5 (Richter), the ground motion is unlikely to be damaging because of its very short duration and moderate acceleration²². Now consider the fact that the Richter magnitude of 4.9 recorded at Koyna could not have been damaging at Koyna. The earthquake shocks of the magnitude of 4.9 (Richter) had to travel to Bombay through the earth. It is now established that as the earthquake waves travel, their intensity diminishes successively at a fast rate. If at the magnitude of 4.9 it could not have caused damage, is it probable that at reduced magnitude on reaching Bombay, they could have caused any? At Bombay, the intensity of waves could be said to be extremely negligible. Mr. Diwan's (Con. W-1) hypothesis does not stand the test of scientific examination or logic.

(a2) *Circumstantial evidence*

141. Let me now test this theory on the basis of circumstantial evidence. Consider these two circumstances :

(i) While scientific information is of primary importance, the conduct of human beings is also eloquent. Now earthquake waves travel in contours. Is it probable that no other part of the Crib Stool system or

²² "Strong Ground Motion"—Article by G. W. Housner.

any other structure in Byculla experienced the earthquake shocks? Earthquakes do not travel like arrows. They travel as waves. Since nothing except the west part of the Crib Stool System was damaged, it does not follow that the earthquake was aimed at the western part of the Crib as Mr. Diwan wants me to believe. Mr. Diwan's assertion that the earthquake travelling from Koyna was directed towards north western angle of the western crib is not only unscientific but is the result of wishful and fanciful thinking. He found that the north western part of the western panel was above the crushed sleepers. He then proceeded to decorate a theory around it. If Mr. Diwan's theory is to be accepted, I will have to imagine that the earthquake waves from Koyna travelled through the crust of the earth with a strong will directed towards Mr. Diwan's structure and finally searched and located the Western Panel of the Crib.

(ii) Mr. Diwan made his affidavit on 10th April 1981. Mr. Joshi made his affidavit on 3rd April 1981. The Contractors wrote to the Director-General of Meteorology on 11th December 1980. The reply dated 16th February 1981 conveying the facts of earthquakes was received by Mr. Diwan (Con. W-1) in the same month. Therefore, the contractors and Mr. Diwan (Con. W-1) were in possession of the facts as to the earthquake shocks, much before they made the affidavits. What would be the natural behaviour of such persons? The first act of theirs would be to place the fact of earthquakes and the case based on them to the forefront. But Mr. Diwan and Mr. Joshi did not disclose in their affidavits that the tilt was caused by the earthquakes. The time between the dates of their affidavits and the date of Mr. Diwan's evidence was utilized for imagining the theory. This conclusion is inevitable because there is no explanation of this omission in the affidavit.

142. The result is that such a magnificent theory was kept as a top secret until Mr. Diwan came into the box. I will examine later on the explanations about this theory made by Mr. Diwan. But for the moment suffice it to say that the circumstances referred to above are extremely inconsistent with the validity of Mr. Diwan's claim. The weight of the circumstances is against Mr. Diwan's opinion.

(a3) Fallacies

143. There are fallacies in the thinking of Mr. Diwan with reference to the earthquakes.

Mr. Diwan has stated that having regard to the seismic coefficient of 0.06 for the Bombay Region which is in Zone III his design makes allowance for additional stress of 9.71 tonnes P.S.I. for each angle of the crib which is 21 per cent more than the allowable stress of 8 tonnes P.S.I. Admittedly, the intensity of the earthquake felt in Bombay is of the Order of II (Modified Mercalli Scale). The design calculations made by Mr. Diwan are naturally on the basis of intensity VII which is the criterion for permanent structures in Bombay. If Mr. Diwan's design takes care of 21 per cent more stress the nearly diminutive intensity of II would cause no damage whatsoever. In

Bombay area, the design forces are required to take care of the earthquake of the intensity of VII on Modified Mercalli Scale. Naturally, therefore, when the design takes care of 21 per cent additional stress on account of horizontal forces, the earthquake of the magnitude of II would not have caused additional stress.

Mr. Diwan (Con. W-1) was aware of the weakness of his thinking. That is why he has further modified his view in paragraph 50 of his evidence. Now he says that the intensity of II would enlarge into intensity of V, if it combines with the vibrations caused by traffic at Byculla. Thus, the earthquake intensity of II alongwith the intensity of vibrations increase the intensity of vibrations to V in terms of Modified Mercalli Scale. The intensity in terms of V of Modified Mercalli Scale. has been described as :

“Felt by nearly everyone ; many awakened. Some dishes, windows etc. broken ; a few instances of cracked plaster ; unstable objects overturned. Disturbance of trees, poles and other tall objects sometimes noticed. Pendulum clocks may stop.”

There is no evidence of any damage of the kind described in the Specification No. V. Mr. Diwan (Con. W-1) has displayed a tendency to assume something which is not in existence. He goes on to assume that there was resonance and such resonance increased the vibrations near the Byculla Bridge to intensity X of the Modified Mercalli Scale. If it is fancied, as Mr. Diwan does, that the vibrations did raise the intensity to Specification X, what would be the results ? This is how Specification X reads :

“Some well-built wooden structures destroyed ; masonry and frame structures and their foundations destroyed ; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Sifted sand and mud. Water splashed over banks of rivers, etc.”

No such damage is proved to have occurred, anywhere near Byculla on that evening. The entire case in paragraph 50 of Mr. Diwan's (Con. W-1) evidence is founded on fanciful thinking. It is utterly without foundation in facts.

144. Then the theory of resonance. There is a basic error in the view held by Mr. Diwan. The first basic misconception is in his diagram (Ex. Con-7) where he has shown impulse load in the form of waves. Earthquake waves are not harmonic motion. The first arrival of wave is the Primary Wave. It is followed by a train of irregular oscillations.²⁹ They are not represented by sine and co-sine graphs. This will be clear from the diagram in the books quoted by me earlier. If the earthquake forces are not harmonic but irregular as in the diagram, the phenomenon of resonance cannot take place at all. Therefore, the entire opinion of Mr. Diwan (Con. W-1) on this aspect based on the theory of resonance will have to be rejected as illogical and opposed to scientific facts.

²⁹“Principles of Physical Geology”—by Arthur Holmes, Second Edition, published by Thomas Nelson and Sons Ltd., London.

145. The tilt occurred at 4-30 p.m. on 26th September 1980 and not earlier. This is clear from the evidence of Mr. Paranjape, the Site Engineer of the Contractors. The earthquake on 25th September 1980 occurred around 7 p.m. The previous earthquake was on 20th February 1980. It is common knowledge that the damage to buildings and structures caused by earthquake results during the time the earthquake lasts. No tilt or damage to timber sleepers was noticed on 20th September 1980. It is, therefore, reasonable to hold that between 20th September 1980 and 25th September 1980 there was no tilt as a result of any earthquake shocks or otherwise. On 25th September 1980 or until 4-30 p.m. on 26th September 1980 no damage to the sleepers or tilt in the axis of the Girder No. 1 was noticed. If this is so, it is safe to conclude that the cracks in the timber sleepers were not caused by the earthquake which occurred on 25th September 1980. If earthquake were the cause, the damage to the sleepers and the tilt would have occurred on 25th September 1980.

(a4) "*May be*"s

146. The weakest part of Mr. Diwan's opinion is his own lack of confidence displayed by him by use of certain words. These words suggest that he was not certain of the correctness of his own opinion. Look at his evidence in paragraphs 49, 50 and 51. He says that the one in a million chance "may" act as to multiply the effect of the first wave. After setting out his view about the concentration of vibrations, he says that the momentary stress "may" cause a crack in the sleeper. Then in regard to the collapse of Girder No. 2, he qualifies the answer by using the word "if". These words signify equivocation and lack of conviction. The opinion of Mr. Diwan is supported not by facts but a number of "*may be*"s.

(b) *Collapse of Girders*

147. In order that the Girder No. 2 which was on the east struck the Girder No. 1, there must be a motion of the Girder No. 2 towards the west. There is absolute absence of such evidence. Mr. Diwan says that "if" wedges were removed from about 15 timber ballies, the Girder No. 2 would move to the west along the arc. This "if" does not supply any facts. In contrast, the evidence reveals certain circumstances which render the removal of the wedges highly improbable. These are the circumstances :

(i) The workers who were engaged during day time on 29th September 1980 continued to work in the night of the collapse. Neither Mr. Paranjape nor Mr. Joshi says that any of the workers had an animus against the contractors or Mr. Diwan. The absence of motive for causing sabotage is an important fact.

(ii) There were three watchmen on duty at the site on the night in question. This would naturally deter any saboteur from attempting such a sabotage.

(iii) Anyone who attempted such a sabotage would have to go underneath the girder for the purpose of removing the wedges. If such

a saboteur intended to cause the collapse, he would naturally risk his life. It is unlikely that anyone would go underneath the bridge and do it. On the face of it, Mr. Diwan's assertion of removal of wedges is so improbable that it has to be rejected.

148. The theory of Girder No. 2 striking Girder No. 1 is built around the distances of the girders from their original positions. According to Mr. Diwan, the distance at which the Girder No. 1 was found at the south end was not likely if it were to fall first. Therefore, he infers that it must have been struck by a strong object which, in the circumstances, must be the Girder No. 2. As against this statement of Mr. Diwan, there are two rational and scientific explanation as to why the girder fell at such a long distance. Both these reasons emerge from the evidence of Dr. Gupchup. The Girder No. 1 was prestressed for the first stage. At this stage, it was vertical and its deadload acted downwards and the prestress gave the upward force. On 29th September 1980 the Girder No. 1 was in a tilted position. In such a position, as the tilt increases, before the collapse the deadload continues to act downward, but the prestress forces acts initially in an inclined direction and then horizontally. This horizontal force on account of prestress cannot be counterbalanced. When the girder collapsed, the operation of the horizontal force throws it away. That is how the Girder No. 1 fell away from the portal frame. There is no challenge to this explanation. Mr. Diwan was present in the court when Dr. Gupchup was cross-examined. Dr. Gupchup was not questioned about the correctness of his opinion as to the fall of the girder at a distance of 15'. The only suggestion was that this is not found in the report. The report was not intended to explain the distances. The three experts were concerned with the cause of the collapse and not with the theory now advanced by Mr Diwan.

The second circumstance is this. The Girder Nos. 1 and 2 were at a height of 2.3 metres from the portal frame. This means a height of over 6'. The position of the girder falling from the portal frame and the position from the height of 6' should be borne in mind. From a height of 6' above the portal frame the girder would not fall near the portal frame. The girder which was at a height of 2.3 metres would naturally fall far away from the portal frame. This explains the distance at which the girders were found on the ground.

Both these are scientific explanations, whereas Mr. Diwan's statement is mere imagination.

149. There is one more reason why Mr. Diwan's opinion is erroneous. If Girder No. 2 were to strike Girder No. 1, Mr. Diwan has not explained as to how a broken portion of the Girder No. 2 was found still hanging from the portal frame, when I visited the site and when the photographs were taken by the Panel of Experts.

Against the background of these facts, Mr. Diwan's theory that the Girder No. 2 struck Girder No. 1 thereby causing collapse of both the girders is completely untenable and has to be rejected.

(c) *Conclusion—Mr. Diwan's opinion.*

150. For the reasons stated in the foregoing paragraphs of this part, I am of the opinion that the fall of the Girder No. 1 was not caused by the impact of Girder No. 2. The cracks in the sleepers did not develop because of the vibrations caused by earthquakes on 20th September 1980 and 25th September 1980. The Girder No. 2 did not fall first. No facts to prove such a fall of Girder No. 2 have been brought forth. The theory advanced by the Contractors is contrary to the facts proved in this inquiry. It is, therefore, Girder No. 1 that fell first bringing down the Girder No. 2 subsequently.

I reject the Contractors' theory advanced through Mr. Diwan

(iv) **VALIDITY OF THE OPINION OF THE PANEL—DR. GUPCHUP**

151. The opinion of the Panel as to the cause of the collapse has been summarised in paragraph 138 *ante*. I will now examine the validity of the opinion of the Panel of Experts. I have rejected the opinion of Mr. Diwan, and the Contractors. Having done this, the only version about the cause of the collapse is the one presented by Dr. Gupchup.

(a) *The Tilt—Cracks in the Sleepers*

152. The causes discernible from the testimony of Dr. Gupchup and certain circumstantial evidence may be summarised as under :—

The crib stool system was overstressed as stated in paragraphs 4.6, 1.4 of the report Exhibit C-6. The Panel of Experts has taken into account the worst case of dispersion of load through the bottom of the crib. On this assumption, the bearing stress can be 213 Kg./Cm² which according to them is very high. The overstress caused the cracks in the sleepers.

153. I will first judge whether this calculation made by the Panel has met with any challenge. The Corporation has not offered any challenge to this part of the evidence of Dr. Gupchup. The only attempt made by counsel for the Corporation was to establish that the diagonal flats of the crib stool system of the cribs were intended to carry the loads. While it is not disputed by Dr. Gupchup that under certain circumstances the diagonal flats of the crib stool system may carry negligible amount of load, his assertion that the timber sleepers were overstressed has not been called into question. The Contractors' Counsel too, has not been able to carry the matters any further except suggesting that the load on the crib stool system was evenly distributed. Nor is the character of Dr. Gupchup as an Expert been subjected to any criticism. In paragraph 77 of his evidence, Mr. Diwan was asked :

“How much stress was transferred to the end panels by dispersion ?”

His answer :

“This cannot be calculated.”

This means that there is no evidence about the dispersion of stress. Mr. Diwan's case is thus vague and nebulous. Dr. Gupchup too was asked to state the distribution of loads carried by the central portion and the end panels of the cribs. This cannot be expected of any expert, as it calls for elaborate calculations. Therefore, the percentage of the load distributed through the diagonal flats could not be given. However, Dr. Gupchup did assert that the central angles took the entire load of the girder. This seems to be consistent with the probabilities because the central angles would naturally take the loads unless the load is distributed to the end panels. The failure to give percentage of loads carried by the end panels does not adversely affect the evidence of Dr. Gupchup—especially, because his statement that such percentage is negligible has not been shaken. Between the nebulous vague assertion that load was distributed to end panels, and the carefully calculated stress of 213 Kg./Cm². I think, it is safe to accept the latter.

154. The opinion as to the capacity of the steel cribs and the system is based upon the design calculations furnished by Mr. Diwan. The design calculations originally submitted to the Corporation form the basis on which Mr. Diwan founded his system (*see* Appendix 'D' to Exhibit C-6). Mr. Diwan is bound by his own design calculations. In these calculations only four timber props have been shown in the crib. It is rational to accept that there were only four vertical props each of 2½" cross-section. During their investigation, the panel asked for a diagram showing the crib stool system with reference to the additional supports given to arrest the tilt. Mr. Diwan took this opportunity to improve and indeed added four more props without stating their diameter. The diagram which was drawn subsequently (Appendix 'J' : Exhibit C-6) shows twice the number of timber props between the cribs. If the design calculations show only four vertical props between the cribs and resting on the timber sleepers, it is reasonable to hold that, that was the correct number of timber props used. I do not accept the Contractors' version based on an assumption that there were eight timber props since the original design shows only four timber props. I hold that there were only four timber props inside the cribs. The diagram prepared by the Contractors' Consultant in response to the Panel's request was designed to draw unfair advantage. If eight props were used in the crib stool system, the design calculations would have shown them. The conduct in causing such improvement was designed to mislead this Commission into committing an error. I reject it. The answers secured by the Contractors' counsel on the assumption that eight props were used, are, therefore, of no significance.

155. Dr. Gupchup was then asked to state reasons for his conclusion that there would be no effective transmission of load through the diagonal flats of the cribs. The answer is logical. The transmission of load through the vertical angles is downwards. The timber sleepers directly support the four angles. Therefore, the load would be transferred to the sleepers vertically. The suggestion that load gets dispersed through the flats joining the central angles was promptly rejected by Dr. Gupchup. He did not rush to give

hurried calculations to support his opinion. Mr. Diwan did so. Dr. Gupchup explained that it was difficult to give such calculations about the capacity of the diagonal flats because it requires extensive calculations.

156. The whole cross-examination of Dr. Gupchup was based on the assumption that eight props were used. This assumption is unwarranted and is based on a drawing prepared to bolster up an imaginary version. In scientific investigation there is no place for assuming such facts. Calculations have to be made on the basis of actual number of props, which on Mr. Diwan's own design were four. I reject the assumption of the Contractors that eight props were used as shown in the diagram. This immediately diminishes the value of Mr. Diwan's evidence, as also the value of cross-examination based on the unwarranted assumption.

157. There is a variation in the diameter of the timber props used in the steel crib system. This is a further improvement. Whereas the design calculations show that the timber props had a diameter of $2\frac{1}{2}$ " in the drawing annexed as Appendix 'J' to the report, the diameter of the timber props have not been mentioned. During the cross-examination, diameter of 3" was suggested though the drawing does not state the diameter. Such a drawing cannot be the basis of evidence. Therefore, the original calculations (Appendix 'J' Exhibit C-6) bring out the true picture of facts. The subsequent improvements were made to suit the Contractors' version in this inquiry. Dr. Gupchup called attention to these variations in the original design and the drawing (Appendix 'J'). Even so, Dr. Gupchup was asked to assume that the diameter of the timber props was 3" and there were eight props. The entire cross-examination as to the load bearing capacity of the system was founded on assumptions and not on facts. This itself is sufficient to reject the version suggested by the Contractors. Even so, I will examine the effect of the answers of Dr. Gupchup on the assumption that there were eight props each of 3" diameter. There is a further assumption that the contact between (i) the crib angles and timber sleepers and (ii) the timber sleepers and the vertical props, were full and complete. The stress calculated in the Court by Dr. Gupchup was 2,150 lbs. P.S.I. in respect of the central angles. This was relied upon to suggest that the crib stool system whose angle would bear 2,150 lbs. P.S.I. was safe. According to the Contractors, therefore, the inference that the system was overstressed is erroneous.

158. The submission of the contractors is erroneous. The calculations made by Dr. Gupchup at the invitation of the Contractors' counsel prove that the system was overstressed. The reasons are as follows :

(i) The permissible stress in timber parallel to the grain would be about half tonne P.S.I. equal of 1,100 P.S.I. The permissible stress in timber perpendicular to the grain would be about 50 per cent of the above stress, that is to say about 600 P.S.I. The timber sleepers were loaded perpendicular to the grain. If additional 25 per cent extra stress is added having regard to the diameter, the permissible stress would be 750 P.S.I.

(600+150). This will demonstrate that the stress of 2,150 based on the assumption provided by Contractors' counsel during the cross-examination is far in excess of the permissible stress. Now if this is the answer of Dr. Gupchup in reply to the question of the Contractors' counsel, it is clear to me that the stress of 2,150 lbs. P.S.I. is far in excess of the permissible stress. Therefore, the crib stool system was overstressed.

(ii) Now consider that the timber props were of $2\frac{1}{2}$ " diameter as shown in the design calculations. If the contact of these props with the surface of the sleeper were not full and complete the stress under the vertical central angles will increase by 15 per cent to 20 per cent. Now with incomplete contact of the props with the sleepers there is an additional increase of 15 per cent to 20 per cent. This increases the stress on the already overstressed system.

(iii) The area of $2\frac{1}{2}$ " diameter prop is about 35 per cent of the area of 3" diameter prop. Thus a $2\frac{1}{2}$ " diameter prop carries less load and the angles will carry more load.

(iv) Add to this, the additional stress on account of hogging. The conclusion that the system was overstressed is impossible to escape.

159. In any view of the matter, I have no doubt, that the crib stool system was overstressed. I am of the opinion that Dr. Gupchup's view that the system was overstressed resulting in the cracks in the three timber sleepers appears to be rational and consistent with the calculations made by him. This provides a scientific explanation of the cracks.

160. Alternatively, there is a likelihood that the sleepers which cracked were damaged. This appears to be consistent with the probabilities provided by circumstantial evidence. The circumstances are these :

(i) The stress on the southern as also northern ends were identical. No sleepers on the northern side had cracked. If all the timber sleepers were healthy and sound, this was unlikely.

(ii) No sleeper on the eastern side of the southern crib stool system had cracked.

(iii) The evidence shows that a number of timber sleepers lying at the site had cracks, though the depth of the cracks has not been proved.

In view of these circumstances, it is not unlikely that the timber sleepers which cracked were not in good condition thereby making them vulnerable.

161. In my opinion, therefore, the timber sleepers cracked because of the overstress. The cracks in this sleeper caused the westward tilt of the girder.

(b) *The Collapse of the Girders*

162. The following factors as cause of the collapse have been eliminated having regard to the evidence, which I have discussed earlier :

(i) The earthquake did not cause any stress on the crib stool system and consequently was not responsible for the collapse.

(ii) The Girder No. 2 did not move along the arc as propounded by Mr. Diwan and the Contractors. Such a movement was, in the circumstances, impossible and the theory is imaginary.

(iii) Inadequate prestress did not cause the collapse.

(iv) The undesirable centering system was not responsible for the collapse.

(v) The concrete used in the girder was excellent. This too, was not the cause of the collapse.

163. After eliminating the causes mentioned in the previous paragraph, what is left is the overstressed crib stool system over the portal frame on which the Girder No. 1 rested. The tilt of the girder was noticed on 26th September 1980. The temporary measures such as packing and propping were necessary. But surprisingly the temporary packing and propping were given not on the western side only but also on the eastern side. Having accepted the evidence of Dr. Gupchup, I am satisfied that the packing and propping of the girder on the eastern side could increase the tilt if the packing was tight. I do not see why additional props were introduced on the eastern side. The packing and the propping aggravated the tilt and the overstressed condition of the Girder No. 1. Mr. Diwan has belatedly made a claim that he had instructed the Site Engineer and the Carpenters to ensure that the packing on the eastern side was light. According to him, in view of this light packing the condition of the girder would not have aggravated. I am sorry to record that the most crucial facts relevant to this inquiry have been brought forth by Mr. Diwan only when he was driven to the wall. The Affidavit made several weeks before the evidence was given provided an excellent opportunity to put forth important facts. They have been disclosed for the first time in the evidence. There is no explanation as to why such crucial facts were held back from the Commission and brought forth in the oral evidence when Mr. Diwan was cornered. That the packing was light had never been stated until Mr. Diwan came in the witness box. This diminishes the value of the statement that the packing was light. However, there is no doubt that the system was overstressed. This condition of the Girder No. 1 ought to have been removed by taking immediate steps to relieve the crib stool system of the overstress. No such step was taken between 26th September 1980 and 30th September 1980. The result was that the weakened and overstressed crib stool system was left to carry the load of the girder. There is no evidence of any observed increase in the tilt. But the girder did not collapse because of the inadequate prestressing or because of poor quality of concrete. In the circumstances, the tilt must have increased before the girder collapsed. The tilt could have increased at a very fast rate and nobody could have noticed it on that night. Thus the weakened temporary crib stool system gave way. Thus the Girder No. 1 collapsed.

164. The girder weighing 72 tonnes collapsed on the ground on the western side. I am satisfied from the evidence of Dr. Gupchup that this massive girder when it fell down caused vibrations thereby disturbing the

centering system of Girder No. 2. It is because of this that Girder No. 2 also came down.

165. Mr. Paranjape's evidence is that after first loud noise, the noise continued for a few seconds. This is consistent with the opinion of Dr. Gupchup in regard to the cause of the fall. Secondly, the centering of the Girder No. 2, as evident from the photographs was lying in such a condition that it suggests that the Girder No. 2 collapsed in the manner suggested by the Panel of Experts. It is not suggested by the Contractors that if the system was overstressed, collapse could not take place in the manner stated by Dr. Gupchup. There is a controversy about the fact of overstress. But it is not disputed, that if the Girder No. 1 was overstressed, it would collapse in the manner stated by the Panel.

166. I am of the opinion, therefore, that the Girder No. 1 collapsed because :

- (i) The weakened overstressed temporary crib stool system gave away ;
- (ii) The failure to take any steps to relieve the crib stool system of the load of the girder ; and
- (iii) The introduction of additional packing and propping on the eastern side on the south portal frame.

Girder No. 1 when it fell down caused vibrations which disturbed the centering of the Girder No. 2, which too fell down.

IV. CONCLUSIONS ON PART IV

167. Having considered all the evidence on record, my conclusions about the cause of collapse are these :

(a) The Girder No. 2 did not strike the Girder No. 1 horizontally from the eastern side as propounded by Mr. Diwan.

(b) The earthquakes of 20th September 1980 and 25th September 1980 were so small in magnitude that they did not have any effect on the temporary crib stool system.

(c) The cracks in the three timber sleepers on the southern portal frame were caused because the system was overstressed for reasons already stated.

(d) No step was taken by the Contractors to relieve the overstressed crib stool system of the load of the girder thereby allowing such a weakened system to carry the load for four long days. As a result of this, the Girder No. 1 tilted along its axis and collapsed in the early hours of 30th September 1980. Centering of the Girder No. 2 was disturbed by the vibrations caused by the fall of Girder No. 1. Therefore, Girder No. 2 also collapsed.

PART IV—*Concluded*

PART V
THE ENGINEERS—WERE THEY NEGLIGENT ?
I. THE LAW

(3) Ingredients

168. In its ordinary meaning, negligence signifies an attitude of carelessness towards and an indifference to the consequences of some act or omission by the person who does the act or makes the omission. However, in the language of Law it has a different meaning. The concept of negligence has three elements :

- (i) A duty to take care.
- (ii) A breach of that duty.
- (iii) Consequential damage to person or property.

169. For comprehending the true perspective of the idea of negligence, different aspects of the ingredients of negligence and their application will have to be considered.

(ii) Duty of Care

170. A relevant question is : to whom is the duty owed ? In a civil dispute it is alleged that the defendant owes a duty of care to the Plaintiff—or a Surgeon owes a duty of care to the patient. In this inquiry there is no Plaintiff or defendant. Whether any Engineer of the Corporation or the Contractors was negligent has to be decided. To whom do the Engineers owe a duty to take care ? In the circumstances in which the inquiry has been instituted, the consideration of duty is with regard to the collapse of the bridge and, therefore, to the work of constructions of the bridge. This, in turn, means that the duty, if any, is owed to the Municipal Corporation. The Engineers who are employed by the Corporation owe the duty by virtue of their relationship. The Contractors and their Consultant may owe a duty to take care because the contract creates a relationship which implies such duty or because the circumstances and the nature of the work require such a duty.

171. Reasonable care to avoid acts or omission should be taken by certain persons. The duty to take care in carrying out certain work may arise because of the very nature of the work. Such duty is owed to those who are so closely or directly affected by the act in question.²⁴ The person undertaking any work must take reasonable care to avoid injury, which he can reasonably foresee.

* 172. The duty to take care exists apart from the contract. Even though the Contract may not imply such duty, the duty may be disclosed by the circumstances in which the parties are placed. For instance take the case

²⁴ Donoghue v. Stevenson (1932) All. E.R. 1.

where Professional men are employed to do certain work. Professional men possessing special knowledge and skill are expected to bring such knowledge and skill into their work. These men are different from ordinary men. Their special calling imposes on them a duty to take care in their work.²⁶ This is so because their knowledge and skill are relied upon by those who are affected by the work. Knowledge by the Professional men that their knowledge is relied upon, firmly establishes their duty to take care.

(iii) Standard of Care

173. It is the duty of the Court, if necessary, to define what is the Standard of Care required.²⁶ In all cases where the question of negligence arises the Standard of Care is that of a prudent and reasonable man. Who is the prudent man contemplated by the Law? He is the man who possesses the skill to do the act or work which he undertakes. The man who undertakes the work without possessing the Special skill is imprudent in undertaking the work, however, careful he may be.²⁷ So also a person while possessing such skill fails to apply it behaves imprudently.

174. The person who undertakes the work must use reasonable care. The Standard is that of a reasonable man. The individual judgment and idiosyncracies are irrelevant.²⁸

The reasonable man is presumed to be free from over-apprehension and over-confidence.²⁹ The reasonable man must foresee the consequences which might ensue from his act or omission.³⁰

(iv) Degree of Care—Professional Men

175. The practice of a profession or calling which demands special skill, ability or experience carries with it a duty to exercise the amount of ability, skill or experience which it demands. If the person is an agent, he is bound to use such skill as may be required by the contract with the Principal.

176. Degree of care varies with the obviousness of the risk. Now risks and new circumstances impose new duties.³¹ Suppose a person is highly skilled about a particular work. He knows the risks involved. Another who is not so skilled does not know the risks involved. The former will be guilty of negligence if he fails to use the skill.³²

(v) Illustrative Cases

177. A person who owes a duty is expected to reasonably foresee the likelihood of danger or accident.³³

²⁶ *Candler v. Grane Chrishman and Company* (1951) 1 All. E.R. 426 (Donning L.J.).

²⁷ *Halsbury's Law of England*—3rd Edition, Volume 28, page 10.

²⁸ *The Law of Torts* by Ratanlal and Dhirailal—20th Edition, page 332.

²⁹ *Glasgow Corporation v. Muir* (1943), 2 All. E.R. 44.

³⁰ *Glasgow Corporation v. Muir* (1943) 2 All. E.R. 44.

³¹ *Veeran v. Krishnamurthy* (A.I.R. 1966), Kerala 172.

³² *Franklin v. Bristol Tramway Company* (1941), 1 All. E.R. 188.

³³ *Franklin v. Bristol Tramway Company* (1941), 1 All. E.R. 188.

³⁴ *Hay or Bourhill v. Young* (1942), 2 All. E.R. 396.

Those who engage themselves in works carrying risks of injury to property or person are liable for the negligence. Such situations are not confined to the known cases. Cases of negligence can arise in indefinite ways. They are never closed. Those who engage in operations which are inherently dangerous must take precautions which are not expected of persons engaged in the ordinary routine of daily life.³⁴

If an anaesthetist of five months standing is employed and allowed to administer anaesthesia without adequate supervision negligence is clear.³⁵ This case highlights adequacy of experience as a criterion in negligence.

(vi) The Principal and Agent

178. Where a Building Contractor engages a Consulting Engineer who gets himself involved in the works by virtue of the contract the question arises about liability of such persons for negligence. As a General Rule, the principal is liable for the wrongful act of his Agent. The liability rests on the ground that the principal is a person who has selected the Agent. However, the act which is alleged to constitute negligence must have been done by the Agent in the course of his employment.

The liability of the Principal for the wrongs of his agent is joint and several with the Agent.

(vii) Error of Judgement

179. There are acts or undertakings in the course of which certain emergencies arise. Such emergencies do not leave any time for reflection or taking a calm decision, nor is there any time to plan the prevention of the accident. Such cases arise where a Pilot flying an aeroplane is faced with situations in which things happen in quick succession. For example, the engine cuts dead, false fire alarms—signals are received, the engine fails and so on. All this happens within the short span of a few moments. This situation creates such a great emergency that no reasonable exercise of foresight, care or skill would have prevented the accident which caused the injury. It is such situations that are properly considered in Law as giving rise to errors of judgement. There is no time to reflect, no plan to design. A decision has to be taken in a split second. It is here that errors of judgement may arise and it would be unjust to characterise exercise of the judgement as negligence. All that has to be seen is that the Pilot has exercised the degree of skill and care called for in such circumstances. But where a work has been planned for several months there was time to anticipate difficulties arising in the work and generally there were opportunities to foresee the danger.

In such cases, the question of error of judgment does not arise.³⁶

³⁴ Corporation of Glasgow v. Muir and Others (1943), 2 All. E.R. 44.

³⁵ Jones v. Manchester Corporation (1952), 2 All. E.R. 125.

³⁶ Indian Airlines Corporation v. Smt. Mahuri Chowdhari and others (A.I.R. 1965), Calcutta 252.

II. PERSONS CONCERNED—THEIR DUTIES

180. The Engineers who were in charge of the work may be broadly divided into two categories :

(i) The Engineers of the Corporation : Mr. Nawathe, Mr. Umadi, Mr. Sanghadia, Mr. Desai and Mr. Palshetkar.

(ii) Mr. Joshi, Partner of the Contractors and Mr. Diwan, their Consulting Engineer.

(i) The Engineers of the Corporation

(a) Relationship

181. Before going into the acts alleged to constitute negligence, the duties and responsibilities of the Engineers have to be properly understood. In the case of the Engineers of the Corporation, their duties consist of the work assigned to them. Engineers of the Corporation did not volunteer to undertake the work of supervision of the Construction. They are employees on the pay-roll of the Municipal Corporation. By virtue of this relationship they are bound to work at the site and supervise the work of the Contractors, if they are assigned such work. Their employment with the Corporation is voluntary ; but the undertaking of the work of supervision at Byculla is not voluntary. They were bound to work at the site.

182. In a sense, the Engineers of the Corporation represented the interest of the Corporation at the site. In order to judge the scope of their duties and, therefore, their responsibilities the contract between the Corporation and the Contractors must be constantly borne in mind. The various clauses of the Contract to which I will presently call a reference emphasize that the duties of the Corporation and its Engineers are basically supervisory. They have not volunteered to furnish expert guidance at the site nor have they claimed that they have specialised experience in the work of bridge building.

(b) The Contract

183. The contract provides the index to the real nature of the duties of the Engineers of the Corporation. Consider the following terms :

(i) The Contractors are obliged to erect false work in the manner stipulated by the Contract. The arrangement shall be subject to the approval of the Corporation's Engineer.³⁷

(ii) The mode of carrying on prestressing work has been prescribed. The Contractors have an obligation to carry out tensioning under " competent supervision ".³⁸

(iii) The basic obligation to carry out the work successfully does not shift to the Corporation's Engineers. For instance plans of the false-work.³⁹

³⁷ Clause 16-6, Contract Ex. M-35.

³⁸ Clause 17-15, Contract Ex. M-35.

³⁹ Clause 21-15, Contract Ex. M-35.

(iv) Approval of the plans does not relieve the contractors of their responsibility. All work is nevertheless subject to the inspection of the Corporation.

(v) In spite of the approval by the Corporation's Engineer, the Contractor shall be wholly liable for the safety of the works, both temporary and permanent and for the completion of the contract to the satisfaction of the Engineer.

(vi) Execution of the work is the responsibility of the Contractors. All that the Corporation is required to do is to provide facilities for such work.⁴²

(c) *Duties of the Engineers*

184. On a true construction of the various terms of the Contract the picture which emerges is this. The Corporation will post an Engineer in charge at the site. The Engineer will inspect and supervise the Contractors' work. The Corporation's Engineer will approve the plans of the form work, but the approval will not absolve the Contractors of their liability. The execution and completion of the work is the responsibility of the Contractors. The Corporation's Engineer will give necessary facilities. The Engineers of the Corporation have a merely supervisory role. Their presence at the site does not implicate them in the event of any accident because the responsibility for successful completion of the work rests on the Contractors. The Engineers of the Corporation have only one duty—inspect and supervise the work and see whether it is carried out according to the plans. No duty to take care, no duty to foresee dangers can be read into the contract. Nor are they involved in the day to day construction in the same way as the contractors are involved. This means that the duty to care expected of people who carry on such work is not attracted.

(ii) **Mr. Diwan and the Contractors**

(a) *Principal and Agent*

185. In my Report I have been referring to the Contractors in the plural. There are six Partners of Messrs. Model Construction Company. Mr. Joshi was assigned the work at the site. This assignment was in the ordinary course of business of the firm. Even, if Mr. Joshi was the person in charge of the work of Byculla Project, he was there in a representative capacity. The responsibility cast by the Contract was of the firm of Messrs. Model Construction Company and not of Mr. Joshi alone.

186. Mr. Diwan's relationship with the Contractors has been styled as Consulting Engineer. But Mr. Diwan's position is exactly identical to that of the Contractors. I have already referred to this aspect in an earlier part of

⁴² Clause 21-18, Contract Ex. M-35.

⁴³ Clause 5, Additional General Stipulations to the Contract Ex. M-35.

⁴⁴ Clause 5-A, Additional General Stipulation to the Contract Ex. M-35.

this report. But since Mr. Diwan (Con. W-1) is not actually a Partner, his legal relationship with the Contractors has to be found out. Section 182 of the Indian Contract Act defines an Agent to mean a person employed to do any act for another or represent another in dealing with third person. The person for whom such act is done is known as the Principal. Mr. Diwan admittedly was employed to design and execute the work of the Flyover Bridge at Byculla. His own Contract produced as Exhibit Con-8 makes him the Agent of the Contractors. It was Mr. Diwan who was concerned with the execution of the work alongwith Mr. Joshi representing the Contractors.

(b) *Consulting Engineer*

187. On general principles, the incidents of the status as Consulting Engineer are as follows :

Consulting Engineer is employed under a contract or services. Under that Contract he is the Agent of his Principal in regard to relations with third parties and his duty towards them is regulated entirely by the terms of the contract with his Principal. One of the implied terms of such contracts is that the Consulting Engineer will be liable for the lack of skill and tort of negligence under the Contract.⁴³

The Consulting Engineer is responsible for all acts or omissions of his employees which amount to negligence. Acts of his employees done with his authority which cause damage to his Principal's interests will raise a presumption of negligence under the Contract. If damage is caused to a third party, he may be liable to him in the tort of negligence.⁴⁴

188. The Consultant's role is of the highest importance, where his opinion and guidance are relied upon. The Consultant's responsibility does not cease with the preparation of the design and drawings for his clients. The ethics of his profession requires him to guide his client in successfully translating his design, into an actual structure, irrespective of whether there is a contractual obligation on him to do so or not.⁴⁵

189. Now, therefore, the Consulting Engineer, Mr. Diwan conceived the bridge. He prepared the drawings. It was his duty to see to it that the bridge as conceived by him came into being. The Contractors' and the Consultant, therefore, were obliged to see that the bridge was built in accordance with the design. This responsibility necessarily implies that all steps necessary to bring the bridge into being should be taken. This responsibility has to borne in mind in judging as to whether any of the Engineers were negligent.

⁴³ " Law and the Engineer " written by Christopher F. Mayson, published by Chapman and Hall Limited, London, 1955—page 392.

⁴⁴ " Law and the Engineer " written by Christopher F. Mayson, published by Chapman and Hall Limited, London, 1955—page 393.

⁴⁵ Paragraph No. 6.3 of the Report of the One-Man Commission of Inquiry on the Collapse of Two Spans (Under Construction) of the Safdarjung Flyover. Prof. G. S. Ramaswamy, Director, Structural Engineering Research Centre, Roorkee and Co-ordinating Director, C.S.I.R., Madras was the Chairman. Dr. M. G. Tamhankar, Head, Bridges Division, structural Engineering Research Centre, Roorkee and Shri C. Thandapani, Director, Highways Research Station, Madras were the Assessors.

(c) *The Contractors*

190. The Contractors offered the tenders. They represented that they would be able to fulfil the term of the contract and build the bridge. By their own conduct they have bound themselves to the duties as Engineers. The employment of the Consulting Engineer does not absolve them of the duty to take all steps to bring the project to a successful termination. They were bound to :

(a) Bring all material necessary to fulfil the contract.

(b) Foresee the likely difficulties including the collapse.

(c) After the occurrence of the tilt to mobilise all resources to erect the towers to bring the girder to vertical position.

(iii) **Duty to take Care**

191. It is implied in the very duties of the Consulting Engineer that he takes all measures necessary to effectuate his conception of the bridge. The Contractor's obligation under the contract placed them under an obligation to take reasonable care and exercise foresight.

192. The duty to foresee the possible danger arises right at the beginning of the project. What are the factors that give rise to such a duty ?

(i) Magnitude of the Project. The length, height and weight of the girder.

(ii) The height at which it was temporarily resting.

(iii) The temporary nature of the crib stool system on which the girders were resting.

(iv) The investment of public money in the project.

193. The special character of the project makes it imperative that the Contractors and their Consulting Engineer exercise reasonable care and foresight. The Corporation took care to insist upon the services of the Consultant. Naturally, the Corporation and its Engineers relied upon the association of the Consultant with the project. They relied upon the knowledge, skill and expertise which Mr. Diwan as Consultant professed to possess. This placed on Mr. Diwan a duty of care expected by law. The Contractors, owe the same duty because they selected the Consulting Engineer. Mr. Diwan and the Contractors are not ordinary Engineers. They held out themselves as Engineers capable of undertaking the bridge work and secured the contract. These facts and the factors enumerated at (i) to (iv) leave no doubt that the Contractors and Mr. Diwan were under a duty to take reasonable care and exercise foresight in the execution of the project.

194. It is against the background of the legal principles stated in the previous paragraphs and the duties of the persons concerned that the question of negligence will have to be considered. I have considered this question in the paragraphs that follow.

III. IS NEGLIGENCE PROVED ?

(i) Proved Facts

195. The question whether anybody was negligent will have to be answered with reference to the facts which have been proved in this Inquiry. If the proved facts justify an inference that all the ingredients of negligence are established, an inference of negligence can be drawn. For this purpose, I will set out briefly the facts which have been proved :

(a) The Contractors needed 240 Steel Cribs. The Contractors themselves were not in a position to have them fabricated and own them. They asked the Corporation to procure them from the Railways. As far back as 1979 the Railways expressed their inability to spare the cribs required by the Contractors.⁴⁶ About 100 cribs were then hired from a Contractor by name Gopaldas Vasudeo. Admittedly, no one except Railways could have spared the requisite number of cribs.

(b) Though Mr. Diwan and the Contractors knew the impossibility of procuring 240 cribs which were needed, a design of centering system and the temporary crib stool system based on the use of steel cribs was prepared.

(c) The centering of each girder needed cribs. Thus, from the beginning the Contractors were unable to support more than one girder.

(d) The tilt of the Girder No. 1 on the afternoon of 26th September 1980 was alarming. The workers and carpenters were asked to leave the site. The site was cordoned off by boulders. The Contractors and Mr. Diwan realised that inadequacy in the number of cribs had made it impossible to erect the Steel towers required for bringing the girders to vertical position.

(e) Mr. Diwan and the Contractors rushed to Messrs Shenoy and Company in the middle of the night of 26th September 1980 for the purpose of securing steel cribs. This is a measure of the alarm and panic which they found themselves in.

(f) On the same night they knew that Steel cribs were not available for erecting towers and bringing the tilted girder to vertical position.

(g) On 27th September 1980, the Corporation thought that the tilt was not "desirable". They, therefore, directed the Contractors by written memorandum (Ex. 15-A) to bring the girder to vertical position immediately.

(h) The second stage of prestressing of the Girder No. 1 was to commence on 30th September 1980. For this purpose it was necessary to bring the girder to vertical position.

(i) Between the night of 26th September 1980 and 30th September 1980 no steps to erect any kind of towers or other steps to bring the girder

⁴⁶ See Ex. M. 54, Correspondence with the Railways.

to vertical position, were taken. The Contractors were relying upon the fact that on 1st October 1980 the Steel cribs under the centering system of Girder No. 2 would be available after the first stage of prestressing of Girder No. 2 was complete. They were waiting for the 1st October 1980.

(j) Between 26th September 1980 and 30th September 1980 the Contractors had four clear days to think about the possible steps to bring the girder to vertical position.

(k) The only method of bringing girder to vertical position was erection of trestle towers or towers of R. S. Joists.

(l) In an emergency like these towers of R.S. Joists could be erected, within two days and the girder placed on them vertically.

(m) The Girder No. 1 was to be lowered to its final position on 3rd October 1980. This needed trestle towers. The design for trestle towers was prepared as far back as 1979 but the material required for it was not secured by the Contractors.

(n) Though the tilt was on the western side the additional packing and propping was done on the eastern side also, thereby worsening the situation.

On these facts, I will now proceed to consider whether anyone has been negligent with reference to the collapse of the girders.

(ii) Standard of Care

196. The Standard of Care applied is always that of a prudent and reasonable man. It is necessary now to lay down the Standard of Care expected of the Engineers in charge of this work. Engineers who undertake work of such magnitude must possess not only the ordinary skill required to build a bridge but also the vision to foresee the possible difficulties in the work and gauge the exact magnitude of such difficulties. Where a bridge of such a magnitude was being built at a height of nearly 30' from the ground level, a prudent Engineer should anticipate that an untoward event like a tilt cannot be dismissed as unlikely. Mr. Diwan (Con. W-1) in paragraph 84 of his evidence says that the tilt was not an unusual experience for him. This means that he was aware of the likelihood of such unhappy occurrences. What are the facts which warrant such a Standard of Care ?

(a) A somewhat risky method of resting the girder on the crib stool system was adopted. The use of two different materials having different *moduli* of elasticity calls for cautious and diligent approach.

(b) The fact that the bridge was at such a height of over 30 feet in a thickly populated locality like Byculla is another factor which places on the Engineers the duty to take care.

(c) The next factor is the possession of the requisite amount of steel cribs to meet such untoward happenings. If 240 cribs were needed, the Engineer should not risk the work with 100 cribs especially when

Mr. Diwan was no stranger to such unusual occurrences. A fair stock of cribs necessary to meet exigencies was necessary.

(d) The Engineers were also required to possess the intellectual resourcefulness and comprehend alternative methods if one type of method viz. steel cribs was not feasible. It is during such crisis that the resourcefulness—material and intellectual—is expected.

(e) Where the situation gives a forewarning—as by the tilt—action on an emergency basis should be taken.

These facts called for a high Standard of Care from those in charge of the work.

(iii) The Standard not Observed

197. The work, its magnitude, risk involved and consequences were of a kind which required special care. This is the reason why the Standard of Care should be high⁴⁷.

198. In my opinion, the Contractors and their Consulting Engineer have not displayed the Standard of Care of prudent and reasonable man for the following reasons :

(i) They commenced the work without possessing the requisite quantity of material required viz. the steel cribs. It is not as if the shortage of steel cribs arose suddenly in September 1980. They knew that the steel cribs would not be available. Yet they went ahead with the risky design. A prudent man would have secured the steel cribs and if they were not available would have altered the design. In commencing work with such insufficient material, a great risk was taken. This is obvious from the manner in which the construction of the Lalbaug Bridge and Byculla Bridge went on. Having realised the effect of the shortage of steel cribs the design was changed so that one of the girders rested on acrow pipes. It was possible to design centering of acrow pipes for all girders. Until the steel cribs from one girder were relieved, the work of the next girder would not commence. For this very reason, the centering of the Girder Nos. 1 and 2 did not commence until after the Lalbaug bridge was complete. This method of working is slipshod and demonstrates inherent lack of care and planning.

(ii) The tilt of the Girder No. 1 was a forewarning of what was to come. How would a prudent and reasonable man behave? A huge massive structure was tilted along its axis in a crowded locality of Bombay. The existence of numerous bus routes, vehicles and pedestrian traffic, shops and homes on both the sides are indicative of the congestion in this locality. Anybody with a reasonable comprehension would become conscious of the care expected of him. A prudent man would not run after steel cribs especially when it was known that they were not available with anyone except

⁴⁷Read V. Lyons and company Limited (1946), 2 ALL, E. R. 471.

the Railways. Alternate ideas would be thought of. Attempts to borrow material for trestle towers would be made from the public bodies like the Government of Maharashtra or well-known firms of Contractors. No such effort was made for meeting such grave emergency. A prudent man would take up emergency measures at all levels. The situation itself called for such effort on the part of the Engineers. But the Engineers like Mr. Diwan and the Contractors did not think of these steps. They demonstrated a total lack of foresight and awareness of the danger.

(iii) Mr. Diwan and the Contractors realised the gravity of the situation after the tilt. The rush for cribs and cordoning of the site is evidence of this. But they would not admit their inability to take urgent steps. They kept on telling everyone that it takes 10 days to fabricate the trestle towers. This is not correct. It might take 10 days if X number of welders and cutters are engaged. But if the number of welders and cutters can be multiplied 10 times, the work can be done in a day or two. Eventually, Mr Diwan admitted in Paragraph 83 of his evidence that the towers can be erected within two days. This situation called for work round-the-clock. No attempt in this direction was made. But Mr. Diwan and the Contractors continued to think of a 10-day programme.

Where the possibility of collapse was staring in the face, prudence required an emergency action.

(iv) After the tilt of the girder the whole situation changed. A reasonable and prudent Engineer placed in such a situation would display a high order of care. For this, they had four long days. Not one of these days was utilized for erecting trestle towers. After arresting the tilt nothing was done. It was said that it takes 10 days to erect trestle towers. But did they start fabrication? In any case, they were required to keep them ready on 3rd October 1980. Even if it is accepted that it takes 10 days to fabricate they ought to commence fabrication around 20th September 1980. Otherwise the Girder No. 1 could not be brought to vertical position on the scheduled day. The total lack of preparation highlights the unreasonable and imprudent method of working by the Engineers concerned.

(v) There was no error of judgement. It was plain lack of care. The question of error of judgement arises where decisions have to be taken on a moment's notice. Nothing had happened suddenly that any Engineer would have fallen into committing an error of judgement. It was possible to sit down and take a calm decision as to how the girder should be brought to vertical position. Indeed they knew that towers have to be erected. No judgement had to be exercised. Consequently there was no question of any error of judgement. Four days were sufficient for erecting towers on an emergency basis. This eliminates error of judgement.

(iv) Degree of Care

199. While Standard of Care is always that of reasonable and prudent man, the degree of care varies with circumstances. In the present case the

tilt of the girder of 26th September 1980 created a dangerous situation. The injury to the bridge which is property of the Corporation was so imminent that a speedy, careful and intelligent action was called for. It is this tilt that introduced the need for a special degree of care on the part of the Engineer.

200. The degree of care naturally varies with the obviousness of the risk. What was the risk? A risk of a total collapse of the girder was known to everyone on the night of 26th September 1980. This is why the Contractors rushed for steel cribs on the same night. The degree of care required of Engineers must, therefore, be proportionate to the risk of the collapse of the bridge. The manner in which they harped on absence of steel cribs and their conduct in waiting for 1st October 1980 to dawn, shows a lack of that degree of care which was absolutely necessary in the circumstances of this case. Extraordinary situation calls for extraordinary care. I am of the opinion that the degree of care expected by the risk inherent in the tilt was not exercised. Instead the Contractors and their Consultant gambled for time. They expected that the bridge would not fall until 1st October 1980 or 2nd October 1980. This was not warranted. There was no certainty that the tilted girder would not fall. They were waiting for the steel cribs of the second girder to be relieved. This provides intrinsic evidence of the lack of care of Engineers in charge of such a bridge.

IV. CONCLUSIONS ON PART V

(a) Engineers of the Corporation

201. The standard and degree of care expected of Engineers who are engaged in the actual work of construction must be distinguished from that of Engineers who are not expected to engage themselves in such work. The Engineers of the Corporation had to perform a routine supervisory duty. These men worked at the site for routine supervision as employees of the Corporation.

202. The standard of foresight expected of them was commensurate with their experience and perspective they had of routine construction. None of them claimed to possess expertise or special skill in prestressed girder bridges. To expect from them the foresight of a Consulting Engineer or experienced building contractors would be unreasonable. In their case, the question is : Did they observe such degree of care as is consistent with the circumstances of their employment, experience and role in the work? Were they expected to show the same standard of care as a professional Contractor?

203. The Engineers of the Corporation are employees. They did not volunteer to take the work of supervision of this bridge. It is those who claim specialised knowledge and ability that are expected to demonstrate possession and use of such ability. Mr. Nawathe, Mr. Umadi, Mr. Sanghadia, Mr. Desai and Mr. Palshetkar in their capacity as employees were bound to work at the site irrespective of possession of experience and knowledge. Could any of them have declined to work on the ground that they did not

possess the qualification and experience of bridges? The scope of the employment with the Corporation left them with no other alternative. In such situations it is not possible to expect them to exercise that Standard of Care which is expected of those who undertake the Contract.

This is not to suggest that they had no duties or obligations to perform. Their relationship with the Corporation, background of experience and supervisory function, required them to do only one thing; that is, supervise and inspect the work. The degree of care expected of them is not equal to that of contractors. They had insisted upon the services of Consulting Engineer. Why did they do so? The answer is that they did not possess the expertise required for such work. They considered that the Consultant's prudence and guidance was necessary. Indeed it is admitted that it is the Consultant on whom the Corporation too relied. That is why the contractors were obliged to engage the services of Consulting Engineer. The distinction between the duties of the Corporation's Engineers and of the Contractors has to be borne in mind in judging the degree of care expected of them. Since the Corporation's Engineers were not expected to deal with the situation created by the tilt they cannot be held to be negligent.

204. Test the matter from another angle. While the contractors were in charge of the work, could the Corporation's Engineers be expected to secure steel cribs or erect towers of R. S. Joists? I think the answer should be "No". Then how could they be negligent?

205. It may then be asked: What were they required to do? The Engineers of the Corporation have answered this question by their conduct. Consider their memorandum Ex. 15A, dated 27th September 1980. It was their duty to bring to the notice of the Contractors that the work was not being carried out in a safe manner and call upon them to bring the girder to vertical position. Look at the Clause No. 5 Additional General Stipulation to the Contract Ex. M-35. Even though Mr. Diwan had assured that everything was alright and the tilt was arrested, the Corporation's Engineers did not rest content with his assurance, but took care to impress upon the Contractors the need to bring the girder to vertical position.

206. Their memo dated 27th September 1980 is a manifestation of the care they took. This was all that was reasonably required of them.

207. An extreme step like termination of the contract and getting the work done departmentally or otherwise was not possible. There was no time to do it departmentally. The work could not be given to anybody else. Giving it to another contractor would involve delay. Besides, no one would have undertaken the work after the tilt. The emergency created by the tilt left no scope for this. There was no time for terminating the contract and undertaking the work. In the circumstances, I hold that they did all that they were expected to do.

208. Mr. Nawathe's failure to visit the site after the tilt was brought on record by Commission's Counsel Mr. Rele, I will examine whether this

amounts to negligence. After the written memo dated 27th September 1980 and the assurance by the contractors that they were taking all steps, a visit by Mr. Nawathe was superfluous. He was at the head of the project. Mr. Umadi reported to him the tilt and the steps taken. With the assurance from the Contractors that they were trying to erect towers, nothing else was required to be done. I do not think that Mr. Nawathe's failure to visit the site constitutes negligence.

209. In my opinion, none of the Engineers of the Corporation were negligent with reference to the collapse of the girders.

(b) The Contractors and Mr. Diwan

210. Prudence of an Engineer or any other professional man lies in circumspection and prompt action where a forewarning is received. I am not oblivious to the fact that a prudent and reasonable man is not personification of circumspection. But prudence and reasonableness of a bridge engineer implies certain basic qualities. Is it unreasonable to expect the contractors and their Consultant to possess the ability to foresee that the temporary crib stool system would give way if it is not relieved of the load? To cover up their inability to comprehend the obvious disaster they kept on saying that the bridge was not in a dangerous condition. A casual look at the overstressed system is sufficient to reject such an argument.

211. The Contractors and their Consulting Engineer were bound to plan and execute the work with such reasonable care as will avoid the collapse of the girders. After the tilt, they ought to have foreseen the collapse. In paragraph 195 I have set out the proved facts. Commencing work without adequate material, failure to procure them after seeing the precariously tilted girder, inaction for four days and failure to erect towers of R. S. Joists by engaging adequate number of cutters and welders, packing and propping the tilted girder on the eastern side and omission to approach other authorities for steel cribs are very significant and eloquent facts.

The Contractors and Mr. Diwan were engaged in a massive project of girder bridge. The girder had tilted. One who engages in such operations must be taken to know that if he does not take special precautions—a disaster will follow. In a progressive city, such operations have to be entrusted to Contractors. Building huge bridges in a congested and busy area calls for special regard for safety of the work. Building a girder by itself is not a dangerous operation. But when the girder tilted, it created an obviously dangerous situation. Those who fail to act with foresight and care, do so at the peril of collapse.

Personal considerations such as paucity of money for buying cribs are altogether out of place. The standard of care and foresight are impersonal and admit of no exception based on factors personal to the contractors.

212. Mr. Diwan and the Contractors had no reason to expect that the girder would remain in position until 1st October 1980. This is where they gambled and waited. They had a duty to foresee a possible collapse and take steps to erect towers. They have executed the work in a slipshod unbusiness like fashion right from the beginning. The whole operation of bridge building was carried on without care. The admission that they were waiting for the steel cribs from the second girder highlights that they were acting on chance rather than scientific planning.

213. By its very nature, the work of using timber sleepers has to be carried out under conditions obtaining at the site. Numerous timber sleepers were brought for the work. It is not reasonable to expect the Contractors to have each timber sleeper tested in a laboratory before it is used in the crib stool system. This is not possible under the conditions in which the Engineers work. I am unable to conclude that use of the damaged timber sleepers by itself constituted negligence. Therefore, prior to the tilt of 26th September 1980 there was no negligence on the part of the Contractors.

214. But the tilt of the 26th September 1980 changed the whole situation. It is at this stage that the Standard and degree of care expected of the Contractors and their Consultant becomes relevant. The failure to keep sufficient number of cribs ready was the first stage of absence of care on the part of the Contractors. After the tilt they had four long days to take proper steps to erect towers either of trestles or emergency towers of R. S. Joists. There was no question of designing it because the design of trestle tower was prepared one year earlier. The evidence of Dr. Gupchup which I have accepted proves beyond any doubt that a tower of R. S. Joists can be fabricated and erected within two days. Indeed Mr. Diwan too accepted this in paragraph 86 of his evidence. He says this :

"These towers for lowering the girder the diagram of which I have drawn would take about two days to prepare or fabricate."

I do not think that a person of such intelligence as Mr. Diwan did not understand the force of the question which elicited the answer. It is often said that the truth leaks out through first outlet. This is what happened. The next three questions too, were on this subject. Mr. Diwan answered them after consideration of their meaning and significance. The answers to the next three questions are as follows :

"I agree that these two towers could have been erected within two days. These towers described as trestles are made up of steel. I do not agree that it was possible to secure steel and fabricate these towers overnight."

Now, therefore, the whole series of five answers were about the time taken for fabricating and erecting trestle towers. Mr. Diwan was asked more questions. But when he realised that his answer had damaged the cause which he had come to advocate, he altered his answer and made this statement :

"I now say that it would take two days to erect the trestles. And if they are to be fabricated and erected it would take 10-12 days".

This answer has come as an afterthought. It is inconsistent with the answer given by him earlier. I am unable to hold that Mr. Diwan has given the first answer because of inadvertence or because of mistake. Nor does he say so. He had enough time to explain but he did not give any explanation. I, therefore, hold that Mr. Diwan has made the admission after properly understanding the questions.

The evidence of Dr. Gupchup also points to the same conclusion. I, therefore, hold that the towers by use of R. S. Joists can be fabricated and erected within two days. This was admittedly not done. The failure to take this step as an emergency measure is clear evidence of the negligence of the Contractors.

PART V—*Concluded*

PART VI

RESPONSIBILITY—WHERE DOES IT LIE ?

(i) The Terms of Reference

215. I am asked to determine the “responsibility for negligence”. It is not clear as to what exactly is expected by these words. “Negligence” is a civil wrong which attracts liability to pay damages. I have no doubt that the Municipal Corporation was aware of the distinction between “responsibility” and “liability”. If it is intended to find out who is “responsible” for “negligence”, my answer is this. Those who are negligent. That brings me back to the question—who was negligent? In Part V of this report I have held that all the Partners of the Contractors and Mr. Diwan were negligent. Naturally, they are “responsible” for the negligence. I will briefly set out the reasons as to why they are “responsible”.

(ii) General Principles

216. In view of the elaborate evidence led in this case the boundaries of responsibility for negligence are easy enough to determine. Responsibility is in this case a clearly identifiable factor because it is directly attached to the conduct of those who were negligent. What are the factors which make a person responsible for his acts? The following factors are important :

(a) Voluntary actions of a person are the only ones for which he can be held responsible. This eliminates compulsion of circumstances.

(b) It follows as a corollary that no one who is not capable of knowing the quality of his acts is not accountable for such acts.

(c) The person must possess the ability to control what he did—otherwise he cannot be held liable to legal consequences.

(d) There are factors which excuses one from “responsibility” for his acts. Ignorance and compulsion are two such factors. If a person is compelled to do certain act responsibility does not attach to these acts.

(iii) Application of the Principles—Conclusions

217. My conclusion that the Engineers of the Corporation, in the circumstances in which they were placed were not negligent, finds support from some of the general principles laid down above. They were not Specialists in bridge building nor were they trained in the work of prestressed concrete. Then they were obliged to work at the site where they were posted irrespective of their knowledge and experience. These factors make it clear that they cannot be held responsible for any act or omission.

On the other hand, the Contractors and Mr. Diwan were the only persons who could have prevented the disaster by taking careful action. The Contractors by virtue of the representation in their contract held out a promise that they would carry out the work with safety and accept responsibility for it. Whether they were ignorant of the process of prestressed concrete or not is altogether irrelevant because their responsibility for the work is admitted in the Contract. They agreed to carry out the work in the manner stated in the Contract. They took the work voluntarily, and they knew the nature and quality of the work expected of them. They have not contended that they were not responsible for the safety of the work. Mr. Diwan (Con. W-1) professed to possess the knowledge, expertise and ability to guide the Engineers at the site. By his own conduct he has made himself responsible. His acts as those of the Contractors were voluntary. On the application of general principles. I have no doubt that all the partners of the Contractors' firm and Mr. Diwan are responsible for the negligence, which resulted in the collapse of the girders.

PART VI—*Concluded*

PART VII

THE SUMMING UP

218. The time has come to lay down the pen. A brief recapitulation of the findings will be useful.

(i) Centering—Prestressing—Crib Stool System

219. The work of concreting done in not too scientific a manner has been found to be extremely satisfactory. The centering system designed by the Contractors was undesirable for reasons already stated. The crib stool system was not ideal. The work of prestressing in its manner and results was far from satisfactory. But none of these factors have contributed to the collapse of the two girders.

(ii) Corporation's Engineers—Action Adequate

220. Counsel for the Commission during his cross-examination has brought out certain facts suggesting that the Corporation's Engineers did not visit the site, as expected of them. I am unable to arrive at such a conclusion. Discrepancies in the progress register, the diaries and the Site Muster were pointed out. The Site Engineer's primary duty is to work at the site in a supervisory capacity. They cannot be expected to keep meticulous record like an accountant. The discrepancies between such record and statements of these Engineers in their oral evidence are natural. The Engineers working at the site are expected to concentrate their attention on engineering aspects; keeping record is subsidiary. They are not expected to concentrate only on the record of their movements. If they do so, results may be unfortunate. This is not to suggest that maintaining site record is a superfluous activity. Far from it. The record of diaries, progress register and site muster are essential. But they are intended to aid the execution of the site work. Naturally, too great importance cannot be attached to the discrepancies. I should have been surprised, if there were no discrepancies in the record. When people work in the ordinary course of business and during such business keep a record of the work, a few discrepancies are natural. It would have been surprising, if there were a total agreement between the record and the oral evidence. Notwithstanding the discrepancies pointed out to me, I am unable to avoid a conclusion that all the Engineers of the Corporation worked hard at the site to the best of their ability. Indeed, the record shows that some of them worked beyond midnight and at numerous sites.

221. I am satisfied that the Engineers of the Corporation were not only careful in their work, but indeed took all possible action to prevent the collapse. The Engineers of the Corporation took action by their memo

dated 27th September 1980. This action was adequate so far as they were concerned. They could not have done anything more.

(iii) Mr. Paranjape—Contractors' Site Engineer

222. I have deliberately omitted any reference to the performance of the duties by Mr. Paranjape, the Site Engineer of the Corporation, his duties and responsibilities were different from those of the Contractors and Mr. Diwan. Mr. Paranjape was fresh from the University and had absolutely no experience of the work of such a magnitude. This was the first bridge of his career. It is futile to search in his conduct any evidence of negligence. I have no hesitation in holding that there is no evidence of negligence on the part of Mr. Paranjape.

(iv) The Cause of the Collapse

223. The collapse of the two girders was caused in the circumstances, which I have discussed in this report. It is unnecessary to repeat those circumstances. I have no doubt that Mr. Diwan and the Contractors were the only persons who could have prevented the collapse by careful, timely and engineer-like performance. Their negligence is the immediate cause of the collapse of the two girders. It is the only cause.

(v) Negligence—No Action to Avoid Collapse

224. I am tempted to repeat one fact. The tilt was caused by over-stress suffered by the crib stool system. In all probability, the sleepers which crushed were not good. The duty of care exists right from the beginning of the work. But after the tilt of the Girder No. 1, there was need for foresight. The negligence played a part after the tilt. It was here that care, foresight and professional skill were required. The Contractors and Mr. Diwan failed here.

225. The authorities concerned were the Engineers of the Corporation, the Contractors themselves and Mr. Diwan. For reasons already stated, the only persons who could have, taken action were the Contractors and their Consultant. Erection of towers of R. S. Joists as an emergency measure was feasible. If this was done by engaging requisite number of Cutters and Welders, the collapse could have been averted. Alternatively, the Government of Maharashtra, who are building large bridges could have been approached for help. Well-known Contractors could have also come to help in such an emergency. Nothing of this kind was done by the Contractors. They did not take the action as expected of them as Engineers. Had they erected the steel towers on an emergency basis, the disaster could have been averted. Since no such action was taken, the question of adequacy of the action does not arise.

(vi) Consequences of the Collapse—Mitigation

226. The terms of reference require me to find out the consequences of the collapse and whether any action was taken to mitigate the consequences. There was no loss of human life. The only consequences was

the collapse of the girders resulting in loss to the Corporation. The question of mitigating the consequences does not arise because the damage was complete, with the collapse. It was impossible to mitigate the damage after the collapse.

227. My report is confined to matters which strictly fall within the terms of the reference. What the Corporation should do to avoid such results is not a subject which I should venture to discuss. The authorities concerned will no doubt examine the matter and take into account the experience gained.

PART VII—*Concluded*

REPORT CONCLUDED

G. H. GUTTAL,
Commission of Inquiry,
Byculla Flyover Bridge, Bombay.
(2nd Additional Principle Judge,
Bombay City Civil Court and
Additional Sessions Judge, Greater Bombay).

Bombay, 20th August 1981.

APPENDIX 'A'

COMMISSION OF INQUIRY, BYCULLA FLYOVER BRIDGE, BOMBAY

REGULATIONS OF PROCEDURE

I. Place of Sitting

(1) The Commission will hold its sitting in Court Room No. 20, Bombay City Civil Court, 3rd Floor, Old Secretariat Building, Fort, Bombay 400 032.

(2) The proceedings of the Commission will be conducted in English.

(3) The Office of the Commission shall function from 10-30 a.m. to 2-00 p.m. and 2-45 p.m. to 5-30 p.m. on all days other than the holidays observed by the Bombay City Civil Court. All the hearings of the Commission will be open to the Public. The Press shall be free to report the proceedings of the Commission. However, in order to ensure that publicity will not deter any witness from giving evidence before it, the Commission may, at the instance of such witnesses or party record evidence in Camera and exclude the public and the press while the evidence of that witness is recorded.

II. Public Notice

(4) The Commission shall invite statements supported by affidavits from members of the public who may have in their possession information relevant to the subject-matter of the inquiry.

III. Legal Practitioners

(5) All the parties, individuals or organisations who are in possession of facts relevant to the Inquiry may be allowed to be represented by legal practitioners of their choice.

(6) The Commission is not bound to permit every party or witness to be represented by legal practitioners. As a general rule the Commission considers it just and fair to allow parties to be represented by advocates of their choice. The Commission may, in any given case, refuse to permit a party or witness to be represented by advocate.

IV. Statements and Affidavits

(7) The affidavits to be filed before the Commission shall be verified in the following manner:—

Every such statement shall be supported by an affidavit which should be verified as follows:—

“ I declare that the statements made in paragraph of the foregoing affidavit are true to my personal knowledge, and the statements made in paragraphs are made on information received and believed by me to be true.”

Such affidavit is required to be endorsed by one of the Officers indicated in section 139 of the Code of Civil Procedure, 1908, or by one of the Officers duly authorised by the Commission to administer oath in this behalf, before whom it is sworn in the following manner:—

“ Sworn before me by the deponent who has been identified to my satisfaction by or is personally known to me. The Affidavit has been read out in full to the deponent who has signed it in my presence after admitting it to be correct this day of 1981.”

(8) The Secretary to the Commission and the Sheristedar have been empowered under the Oaths Act, 1952, to administer Oaths for the purpose of filing affidavits before the Commission.

(9) The affidavits may be sent to—

The Secretary,
Commission of Inquiry,
Byculla Flyover Bridge, Bombay,
Bombay City Civil Court, Room No. 145-A, 3rd Floor,
Opposite Main Lift, Old Secretariat Building,
Kala Ghoda, Fort, Bombay 400 032.

They may be sent by registered post or personally handed over to the Secretary or some other person authorised to receive them. A receipt may be obtained.

If the affidavit is in a language other than English, it shall be accompanied by a translation thereof in English.

(10) Every affidavit shall be drawn up in the first person and divided into paragraphs consecutively, each material statement of fact being made the subject-matter of a separate paragraph. The affidavit shall state the description, occupation, if any, and the place of residence or business of the deponent. The persons or organisations filing affidavits shall file 5 spare copies thereof to facilitate exchange of affidavits between the parties.

(11) If the deponent relies upon any document the original document or a duly certified copy thereof shall be filed along with the affidavit. If the original of such document is not in the possession or power of the deponent, he shall disclose the person who is in custody thereof and the address at which he may be contacted. If the document is from official record and the identity of the Officer having its custody is not intended to be disclosed, the particulars of the file containing the relevant information may be indicated.

V. Summonses

(12) The Commission may issue summons to persons whose attendance before it may be required either to give evidence or produce documents.

(13) Every summons issued by the Commission shall be in duplicate and shall be signed by the Secretary of the Commission or by such person as the Commission may empower on its behalf. It shall bear the seal of the Commission.

(14) The summons by the Commission shall be sent by registered post and shall specify the day, date and the time at which the person summoned is required to attend and also whether his attendance is required for the purpose of giving evidence or to produce a document or for both the purposes. The Summons may also be served personally by the party calling a witness or where an advocate has filed appearance for a party, by the clerks of such advocate. The person who serves the summons shall make an affidavit proving service.

(15) A person summoned merely to produce document shall be deemed to have complied with the summons, if he causes such document to be produced instead of attending personally to produce the same.

(16) Blank Summonses for Service on witnesses within the limits of Greater Bombay may be taken out by the permission of the Commission.

(17) The provisions as to issue and service of summons of the Commission shall apply to every other processes issued by the Commission.

(18) The travelling or other expenses, as provided in rule 19, below, shall be paid to the person who is summoned by the Commission either to produce documents or to give evidence.

(19) Every person summoned to give evidence before the Commission shall be paid a reasonable sum for his travelling and other incidental expenses for going to and returning from the

Allowance per Day

- (a) Employees earning less than Rs. 500 per month—Rs. 10.
 - (b) Employees of the status of Gazetted Officers of Government, Bank Managers, Merchants, Editors, Accountants, Brokers and so on—Rs. 15.
 - (c) Professional men, Engineers, Doctors, Lawyers, Architects, Specialists in Hand Writing and Finger Prints—Rs. 30.
 - (d) The Commission may vary these sums or rates having regard to the witness's qualifications, professional standing or experience.
- (20) The Secretary to the Commission will decide as to which class the witness belongs. Witness staying beyond one Kilometre from the place of sitting of the Commission shall be allowed bus or train fare if they belong to class (a) above. Witnesses belonging to classes (b) and (c) if residing beyond the distance of one Kilometer from the Court House shall be paid his actual taxi fare, if the party requiring his evidence has not provided for conveyance for him.

(21) After the evidence is over, the witness shall take an endorsement of the Sheristedar of the Commission on the original summons. The endorsement shall certify the fact that the witness has attended the Commission's Inquiry and the number of days his presence was required in the Court house. The witness shall then take the original summons with the endorsement of the Sheristedar to the Office of the Commission. The Office of the Commission shall then pay to the witness the amount in accordance with these rules and obtain a receipt therefor.

VI. List of Witnesses

(22) Every person or organisation who has filed a statement supported by affidavit and is desirous of giving evidence shall furnish a list of witnesses and shall indicate against the name of each witness the fact for which his oral examination is considered necessary. The Commission may refuse to summon any witness whose evidence it thinks is unnecessary, or irrelevant, or who in its opinion, has been cited for the purpose of delay and vexation.

(23) Registered documents in original, or their certified copies issued by the Registration Department will, as a rule, be admitted without requiring formal proof of their execution. Similarly, official records pertaining to Government departments, statutory bodies, state undertakings and Co-operative Societies including the office notings, orders, etc., may, subject to any valid claim of privilege, be admitted without formal proof unless the Commission in any particular case, requires it to be proved in any of the ways laid down in the Evidence Act.

(24) Technical rules of the Evidence Act and the Code of Civil Procedure as such, do not govern the proceedings before the Commission. However, the fundamental principles of natural justice and fair play underlying the legal system of our country shall guide the Commission in its proceedings.

VII. Oral Evidence—Witnesses

(25) The Interpreters of the Commission shall administer oath in the language of the witness whose evidence is to be recorded.

(26) After examination of all the statements that may be furnished in response to the public notice, the Commission may, if it thinks necessary, call upon any person to give oral evidence and submit himself to cross-examination. In such a case the affidavit already filed may be treated as part of his examination-in-chief. If the Commission decides to record oral evidence, it shall first record the evidence, if any, produced by the Municipal Corporation and thereafter record the evidence in such order as the Commission may deem proper. Provided, however, that the order of examination of witnesses shall be in the discretion of the Commission. The Commission may order the examination of witnesses in such order as it may deem fit.

(27) In case the oral evidence is recorded, and the conduct of any person is inquired into by the Commission or the inquiry is likely to prejudicially affect the reputation of any person, the Commission shall give to such person reasonable opportunity of being heard in the inquiry and produce evidence in his defence. But this rule shall not apply where the credit of a witness is being impeached.

(28) The Commission may, in its discretion, refuse to call any person for oral examination and instead allow him to be examined on affidavit through interrogatories, delivered to him.

Miscellaneous

(29) The Commission may either *sue motu* or on the application of any witness or party delete or expunge, from any affidavit any matter which the Commission considers irrelevant, needlessly offensive or scandalous.

(30) All the record and papers relating to the Office of the Commission and other matters kept by or in the office of the Commission including the evidence tendered before the Commission shall be preserved intact and shall be remitted to Government along with the report of the Commission.

(31) The Commission may alter, modify or add to these regulations of procedure at any time during the course of the inquiry.

By order of the Commission,

I. S. MECWAN

Secretary

Commission of Inquiry
Byculla Flyover Bridge, Bombay

Bombay, 2nd March 1981

APPENDIX ' B '

STAFF OF THE COMMISSION

Municipal Staff

- (i) Mr. R. G. Rane, Office Superintendent
- (ii) Mr. R. J. Patil, Head Clerk
- (iii) Mr. R. M. Potnis, Senior Stenographer
- (iv) Mr. P. G. Shete, Junior Stenographer
- (v) Mrs. P. S. Kunte, Typist
- (vi) Mr. A. S. More, Naik
- (vii) Mr. S. M. Nalodey, Peon
- (viii) Mr. S. S. Shivgan, Peon
- (ix) Mr. M. B. Kamble, Peon

Court Staff

- (i) Mr. I. S. Mecwan, Second Additional Registrar
- (ii) Mr. V. B. Karandikar, Sheristedar
- (iii) Miss V. D. Bolar, Stenographer
- (iv) Miss M. P. Karambe, Court Interpreter
- (v) Mr. I. K. Patel, Havildar
- (vi) Mr. S. K. Rokade, Peon

APPENDIX 'C'

COMMISSION OF INQUIRY, BYCULLA FLYOVER BRIDGE, BOMBAY

Notification

WHEREAS two prestressed girders of the Flyover Bridge under construction by the Municipal Corporation of Greater Bombay near Gloria Church, Byculla, collapsed on Tuesday, the 30th September 1980;

AND WHEREAS the Municipal Corporation of Greater Bombay under Resolution No. 1018, dated 21st November 1980 requested the Government to institute a judicial inquiry for having a fair, free and impartial investigation in the matter and with a view to ensuring confidence of the citizens in the Corporation;

AND WHEREAS by the Government of Maharashtra, Urban Development and Public Health Department, Notification No. BMC/2380/4289/UD-3, dated 28th January 1981, a Commission of Inquiry consisting of Shri G. H. Guttal, Judge of the Bombay City Civil Court has been appointed to inquire into and report on:—

(i) Causes of collapse of the two prestressed girders of the Flyover Bridge under construction at Byculla and the circumstances in which such collapse occurred;

(ii) Whether adequate action was taken by the various authorities before, during and immediately after the collapse to avoid the same or to mitigate the consequences thereof; and

(iii) To determine the responsibility for negligence, if any, on the part of servants and/or Engineers of the Corporation and the Contractors.

AND WHEREAS the Commission is of opinion that it is necessary to obtain all relevant information and evidence pertaining to the subject-matter of the inquiry;

NOW, THEREFORE, BY AND UNDER THE ORDER OF THE COMMISSION, IT IS HEREBY NOTIFIED that—

(1) (i) All persons or Organisations acquainted with any fact relevant to the subject matter of the inquiry to be made by the Commission relating to the matters specified in Clauses (i) to (iii) above, are hereby invited to make a statement of facts setting out therein all information to their knowledge relating to the causes of the collapse, the action which ought to have been taken by the various authorities before, during and after the collapse and setting out whether any one was responsible by reason of negligence or otherwise;

(ii) The statement should preferably be in the English language. If it is in a language other than English a translation thereof in English may be enclosed therewith;

(iii) The statement shall be drawn up in the first person and divided into paragraphs to be numbered consecutively, each material statement of fact should be made the subject matter of a separate paragraph and the person making the statement shall state his description, occupation, if any, and the place of residence or business where he is generally available for receiving communications;

(iv) Where a statement is made by an Organisation it should be made by the Secretary of the Organisation or such other person as may be authorised by the Governing Body of the Organisation in that behalf;

(v) Where statements made are based on the personal knowledge of the deponent, he should say so in the statement and where any such statement is based on any information derived by the deponent from any other person the name and address of the informant, or if the informant is a Government Official or any other public servant, whose identity is not intended to be disclosed, the particulars of the file containing the relevant information should be stated in the statement and the deponent should state whether he believes the information to be true;

(vi) A list of documents, if any, on which the deponent proposes to rely should be forwarded to the Commission along with such of the originals or true copies of the documents as are in the possession, power and custody of the deponent. If any document is not in the possession, power or custody of the deponent, the statement should include the name and address of the person from whom such document may be obtained.

(2) WITHOUT PREJUDICE to the generality of the provisions of sub-para. (1) above such statements may also include all or any of the following matters, namely:—

(i) The technical causes of the collapse of the girders and the precautions taken or omitted to be taken in the process of the construction of the Flyover Bridge or girders;

(ii) The authorities responsible for the construction of the Flyover Bridge, and the supervision of the work;

(iii) Fitness of the material used in the construction of the Flyover Bridge and the girders;

(iv) The design of the work with defects, if any;

(v) Details of the negligence in the carrying out any process of construction or supervision;

(vi) Any information available with the deponent about the cause of the collapse of the girders or the negligence on the part of any Officer or Contractor employed in connection with the girders;

(vii) The reasons and circumstances which in the opinion of the deponent lead to the collapse of the girders and

(viii) The measures which the deponent may suggest for the prevention of the recurrence of such collapse.

(3) Every such statement shall be supported by an affidavit which should be verified as follows:—

“I declare that the statements made in paragraphs . . . of the foregoing affidavit are true to my personal knowledge, and the statements made in paragraphs . . . are made on information received and believed by me to be true.”

such affidavit is required to be endorsed by one of the Officers indicated in section 139 of the Code of Civil Procedure, 1908, or by one of the Officers duly authorised by the Commission to administer oath in this behalf, before whom it is sworn in the following manner:—

“Sworn before me by the deponent who has been identified to my satisfaction by . . . or is personally known to me. The affidavit has been read out in full to the deponent who has signed it in my presence after admitting it to be correct this . . . day of . . . 1981.”

Signature of the Authority.

(4) IT IS FURTHER NOTIFIED that in exercise of the powers vested in the Commission of Inquiry under section 4 of the Commission of Inquiry Act, 1952, read with section 3 of the Oaths Act, 1969, the Commission has empowered Shri I. S. Mecwan, Secretary to the Commission of Inquiry and Shri V. B. Karandikar, Shirastedar in the Office of the Commission of Inquiry to administer oaths and affirmations to witnesses before the Commission and for the purpose of affidavit to be filed before the Commission.

(5) Such statements accompanied by the affidavit shall be forwarded to the Secretary of the Commission of Inquiry so as to reach him not later than Friday the 20th March at the following address:—

The Secretary,
Commission of Inquiry,
Byculla Flyover Bridge, Bombay,
Bombay City Civil Court, Room No. 145-A, 3rd Floor,
Opp. Main Lift, Old Secretariat Building,
Kala Ghoda, Fort, Bombay 400 032.

(6) Section 6 of the Commissions of Inquiry Act, 1952 (Act 60 of 1952) which protects deponents before the Commission from civil or criminal proceedings is reproduced below for the information of the persons intending to furnish information to the Commission:

“ 6. Statements made by persons to the Commission—

No statement made by a person in the course of giving evidence before the Commission shall subject him to, or be used against him, in any civil or criminal proceedings except a prosecution for giving false evidence by such statement ”:

Provided that the statement:—

- (a) is made in reply to a question which he is required by the Commission to answer;
- or
- (b) is relevant to the subject matter of the inquiry.

By order of the Commission,

I. S. MECWAN

Secretary

Commission of Inquiry

Byculla Flyover Bridge, Bombay

Bombay Dated 2nd March 1981

Notification

WHEREAS the Commission of Inquiry consisting of Shri G. H. Guttal, Judge of the Bombay City Civil Court enquiring into causes of collapse of the two prestressed girders of the Flyover Bridge under construction by the Municipal Corporation of Greater Bombay near Gloria Church, Byculla, which collapsed on Tuesday, the 30th September 1980, by its Notification herein, dated the 2nd day of March 1981 invited all persons or organisations acquainted with any fact relevant to the subject matter of inquiry to be made by the Commission relating to the matters specified in clauses (i) to (iii) of Government of Maharashtra, Urban Development and Public Health Department Notification, No. BMC/2380/4289/UD-3, dated 28th January 1981, to make a statement of facts setting out therein all information to their knowledge relating to the causes of the collapse, the action which ought to have been taken by the various authorities before, during and after the collapse and set out whether anyone was responsible by reasons of negligence or otherwise accompanied by affidavits, on or before Friday, the 20th day of March 1981;

AND WHEREAS the Commission on application of the Municipal Corporation of Greater Bombay, was pleased to grant the extension of time to file statement supported by the affidavits etc. before the Commission till Tuesday, the 31st day of March 1981.

It is by and under the Order of the Commission hereby notified that such persons as mentioned in the said Notification, dated the 2nd March 1981 may forward their statement accompanied by affidavits etc. to the Secretary to the Commission of Inquiry, Bombay City Civil Court, Room No. 145-A, 3rd Floor, opposite Main Lift, Old Secretariat, Kala Ghoda, Bombay 400 032, so as to reach him not later than Tuesday, the 31st day of March 1981.

By order of the Commission,

I. S. MECWAN

Secretary

Commission of Inquiry
Byculla Flyover Bridge, Bombay

Bombay Dated 16th March 1981

APPENDIX ' D '

STATEMENTS OF QUALIFICATIONS AND EXPERIENCE OF DR. V. N. GUPCHUP, DR. N. G. BONDRE, MR. R. G. GANDHI AND MR. M. P. GAJAPATHY RAO RESUME

Name—Vijay Narhar Gupchup.

Date of Birth—January 8, 1937.

Address—

Residence : 76 Blue Haven, Mount Pleasant Road, Bombay 400 006, India.

Office : Victoria Jubilee Technical Institute, Matunga, Bombay 400 019, India.

Academic Qualifications—

Bachelor of Engineering (Civil) with First Class Honours from Bombay University in 1958.

Master of Science in Civil Engineering from Massachusetts Institute of Technology, U.S.A. in 1959.

Doctor of Science in Civil Engineering from Massachusetts Institute of Technology, U.S.A. in 1963.

Major Field—Structural Engineering.

Minor Fields—Soil Mechanics and Fluid Mechanics.

Title of the Thesis—Non-linear response of two Hinged Circular Reinforced Concrete Arches to Static and Dynamic Loads.

Membership of Professional Societies—

Affiliate of the American Society of Civil Engineers.

Associate Member of the Institution of Engineers (India).

Member of the Indian Society of Earthquake Technology.

Honour—Fellow of the Maharashtra Academy of Sciences.

Professional Experience—

September 1959 to January 1963—Research Assistant in the Department of Civil Engineering, Massachusetts Institute of Technology, U.S.A.

June 1953 to July 1964—Engineer with Bechtel Corporation, San Francisco, California, U.S.A. in their Hydro-Power and Scientific Development Division.

October 1964 to February 1965—Engineer with Bechtel Asian Corporation, New Delhi, India.

March 1965 to January 1966—Engineer with Engineers India Ltd., New Delhi, India.

February 1965 to September 1967—Practised as Consulting Civil and Structural Engineer in Bombay, India.

October 1967 till to-date—Professor and Head, Structural Engineering Department, Victoria Jubilee Technical Institute, Bombay, India. Also Vice-Principal of the Institute since February 1974.

Important Design Projects handled

Member of the group of engineers in Bechtel Corporation to study the Dynamic Response of Overhead Structures subjected to loading of moving vehicles and also to seismic forces for the Bay Area Rapid Transit System, San Francisco, U.S.A. (1963-64).

Organisation of soils investigation for Madras Refinery Project, India for Engineers India Ltd. (1965).

Consulting Engineer for the design of reinforced concrete structures for the campus of the Jiwaji University, Gwalior, India (1966-67).

Consultant to Messrs. Hindustan Construction Company, Bombay, India to study the possible effects of blasting operations in the quarry in the vicinity of the proposed site for the construction of Indikki Arch Dam in Kerala State, India (1966).

Consulting Engineer for the design of reinforced concrete and steel structures for the office and factory of Kirloskar Pneumatic Company, Poona, India (1967-68).

Consulting Engineer for the design of reinforced concrete and steel structures, including buildings, water-tanks and storage silos of the Silicon Carbide Plant for Grindwell Norton Ltd., Bangalore, India (1971-72) and 1976-77 (work in progress).

Consulting Structural Engineer for the proposed "Development of the Ajanta Hills Area"—Project undertaken by the Maharashtra Tourism Development Corporation (1967-77 work in progress).

Important Research Projects handled

Co-Investigator for the project involving study of "Effects of Re-Vibration on the Properties for Concrete" sponsored by Council of Scientific and Industrial Research, Government of India, New Delhi (1970-72).

Member of the group of Consulting Engineers appointed by the Department of Atomic Energy, Bombay, India, to investigate the dynamic behaviour of Nuclear Power Plants subjected to seismic effects (1971).

Principal Investigator for the project for developing computer programmes for the design of Crane Box Girders, sponsored by Western Mechanical Industries, Bombay, India (1972).

Principal Investigator for the project for studying the "utility of Bamboo as reinforcement in concrete" sponsored by City and Industrial Development Corporation, Government of Maharashtra, India (1972-73).

Principal Investigator for the project involving "the study of the use of fly ash (from the Thermal Power Station at Nashik) in concrete", sponsored by City and Industrial Development Corporation, Government of Maharashtra, India (1973-74).

Principal Investigator for the project involving a large-scale load test of Mahim Causeway Bridge in Bombay during the passage of a special tractor trailer carrying the main reaction vessel of the Nuclear Power Plant at Kota, India,—project sponsored by Power Projects Engineering Division, Department of Atomic Energy, Bombay, India (1973).

Principal investigator for the project for the study of "Effect of reduction in bearing area at splice joints in Columns"—project sponsored by Power Projects Engineering Division, Department of Atomic Energy, Government of India (1976-77).

Papers published

1. "Dynamic Non-linear Response of Reinforced Concrete Arches", presented at the Second Conference on Electronic Computation of the American Society of Civil Engineers in Boulder-Colorado, U.S.A. and published in the proceedings of the A.S.C.E. in August 1963.

Co-Authors—Prof. John M. Biggs of M.I.T., Cambridge, Massa., U.S.A.

2. "Dynamic Response of Multi-storey Frames subjected to Earthquake Ground Motion"—presented at the IV Symposium on Earthquake Engineering held at Roorkee, India in November 1970 and published in the Bulletin of India Society of Earthquake Technology, Roorkee, India in June 1971.

Co-Author—R. M. Desai.

3. "Ways to Economise on Consumption of Cement and Steel in Building Industry", published at the National Consultation on Building Materials organized by National Building Organisation, New Delhi, India in May 1973.

Co-Author—S. Sundaram.

4. "Computer—Aided Design-Crane Box Girders", presented at the Seminar on Material Handling Equipment organised by the Institution of Engineers, Bombay Centre, India in December 1973.

Co-Authors—G. K. Malkani and V. R. Mhaikar.

5. "Suitability of Bamboo Strips as Tensile Reinforcement in Concrete", published in proceeding of the 6th Congress of International Council for Building Research Studies and Documentation held in October 1974 at Budapest, Hungary.

Co-Authors—S. Jayaram and J. N. Sukhadwalla.

6. "Response of a Typical Reactor Building to Strong Motion Earthquake", presented to the V Symposium on Earthquake Engineering organised by the Indian Society of Earthquake Technology at Roorkee in November 1974 and published in Volume 1 of the Symposium.

Co-Authors—V. V. Nori, I. K. Shah and K. S. Parikh.

7. "System of Prefabricated Steel Members for Housing Construction", presented to the All India Seminar on Developments in Construction Technology organized by the Institution of Engineers (India) in December 1975.

Co-Authors—M. D. Mulay and A. R. Naik.

8. "Seismic Analysis of Unsymmetrical Buildings" presented to VI Symposium in Earthquake Engineering held at Roorkee in October 1978.

Co-Authors—S. Sundaram and C. G. Samant.

9. "Seismic Analysis of a large span aircraft hangar" published in the Bulletin of the India Society of Earthquake Technology (March-June 1978).

Co-Authors—S. Sundaram, M. D. Mulay and S. A. Rege.

Special Interest

Problems in Structural Vibrations including Seismic Analysis of Structures, Analysis and Design of Machine Foundations etc. Have been a Consultant to several firms in Bombay in this field of specialization.

Teaching Experience

Subjects taught at the Undergraduate level—

1. Strength of Materials.
2. Structural Analysis.

Subjects taught at Post-graduate level—

1. Advanced Theory of Structures.
2. Advanced Structural Mechanics.
3. Advanced Design of Concrete Structures.
4. Introduction to Operations Research and Computer Programming.

Have successfully guided several students in preparing dissertations for the Degree of Master of Engineering with structural Engineering subjects of the University of Bombay.

Guide to five students working towards Ph.D. in Civil/Structural Engineering of the University of Bombay.

Awards received

Was awarded a Special Prize by the Bombay Centre of Institution of Engineers (India) for organizing and conducting a three-week course on the use of Computers for Structural Engineers.

Other Activities

1. Member of Senate of the University of Bombay elected by the Teachers of Constituent Colleges (1969 to 1976).
2. Member of the Committee of Courses in Civil and Structural Engineering appointed by the Board of Technical Examinations, Government of Maharashtra, Bombay, India.
3. Member of the Board of Studies in Engineering of the University of Bombay, India.
4. Member of the Faculty of Technology, University of Indore, India (1975).
5. Member of Board of Studies in Structural Engineering at Post-graduate level of the Indian Institute of Technology, Bombay, for the year 1969.
6. Member of the Building Committee of the Cement Research Institute of India, New Delhi, from November 1966 to March 1971.
7. Chairman of the Planning Group on "Information and Documentation" for Panel on "Housing and Construction Technology" of the National Committee on Science and Technology, Government of India (1973).
8. Member of the Engineering Sciences Advisory Committee of the Board of Research in Nuclear Sciences, Department of Atomic Energy, Government of India (1973-76) and (1976 onwards).
9. Member of Technical Committee, "Quality Control Criteria" of the Joint Committee of Planning and Design of Tall Buildings,—constituted by American Society of Civil Engineers, International Association of Bridge and Structural Engineering etc.
10. Member of the organising committee for the "Symposium on Structural Mechanics" organised by the Department of Atomic Energy at Bhabha Atomic Research Centre, Bombay in March 1975 and Chairman of the Session on "Dynamics" at this Symposium.
11. Member of several committees for academic evaluation of different Engineering Colleges and Technical Institutes in the Western Region of India—Committees appointed by Western Regional Committee of All India Council of Technical Education, Government of India.
12. Member of the Committee appointed by the Nagpur University for the Government of Maharashtra to prepare Text Books in Civil Engineering in Regional Language (Marathi) for University students.

Name—Narayan Ganesh Bondre.

Date of Birth—20th March 1931.

Qualifications—B.Sc. (Physics and Mathematics), Bombay, 1950; B.Sc. (Civil Engineering), London, 1953; Ph.d., London, 1957.

Experience—

1955-57—Senior Technical Assistant, Port of London Authority at Tilbury and Surrey docks.

Work involved concrete mix design, quality control of site concrete, setting up and running concrete testing laboratory and site work.

1958-60—Design Engineer with Uttam Singh Dugal and Co., New Delhi.

Work consisted of designing various structures, mainly prestressed concrete bridges and design and site supervision of Grey Iron Foundry at Rourkela Steel Plant.

1960-61—Partner, H. Moller and Co., New Delhi.

Handled mainly design of prestressed concrete bridges and construction equipment such as launching girders, gantries and slip form shuttering.

Since 1961 to-date—Independent practice as Consulting Structural Engineer at Bombay Since 1964, Partner, Dubon Engineering Company.

Since 1975, Director, Dubon Project Engineering Pvt. Ltd.

Major Assignments handled—

Hotel Oberoi Sheraton, Bombay—At Thirty storeys, tallest building in Bombay. Two basements, lowest level being 25 feet below high tide level. Diaphragm wall with prestressed anchors was used. At some points, basement level is 10 feet below lower most level of diaphragm wall. Superstructure is cast *in situ* R.C.C. main earthquake resisting system is moment resisting ductile concrete frame work, designed and detailed according to SEAOC Code. Analysis was carried out on CDC 3600 Computer, where elastic deformations and torsion of building were accounted for. With proper co-ordination it was possible to achieve a best rate of 9 days between casting of two slabs; average being about 14 days.

Cost of civil works—Rs. 60 million.

NPK Fertilizer Plant at Kandla—Entire civil works handled by Dubon Engineering Co. under overall contract executed by Dorr-Oliver (India) Ltd.

Complex consisted of main NPK Plant, bagging plant, bulk storages, acid tanks, administration buildings, site filling, roads, drains etc.

Soil conditions were very poor and foundations ranged from piles, stone columns, sand drains, with preloading to untreated soil depending on type of structures. Very close co-ordination was established between structural designers, soil consultant and equipment suppliers to determine permissible settlements, type of flexible joints to be used and ultimately use of suitable foundations and structures. Considerable economy was achieved by this process. Structures themselves included R.C.C. frame works, structural steel supports and prestressed roof members. All the structures were suitably designed for very heavy seismic forces in this area.

Total cost of civil works—Rs. 50 million.

Industrial Complexes for Mahindra Group of Companies—Over the last 15 years industrial sheds of an aggregate area of approximately 1 million square feet have been built by this group to our designs and supervision. Special precast and prestressed concrete designs most suited to Indian conditions have been evolved. This is more economical than structural steel sheds. Problems of maintenance are practically eliminated.

Total cost of civil works approximately Rs. 30 million.

Bridge over river Neman—A bridge of about 400 feet total length, with special foundation technique.

Trial bores indicated hard stratum of only 5 feet thickness at depth of 30 feet while real hard stratum exists at depth of 50 feet. Well sinking was therefore not practical nor conventional piling. The foundation technique evolved was to bore a hole using bentonite slurry corresponding to pile diameter. Pile was then cast above the hole six feet at a time and lowered into the hole. The annular space was then grouted. The superstructure is with prestressed concrete girders and R.C.C. slab. The new foundation technique was developed jointly with Mr. K. R. Datye, who is also a Director of DPE.

747 Wing Hangar at Bombay—Hangar consists of 220 feet span structural steel portals with A.C. sheet roofing. Portals were made of box section using angles at corners with diagonal bracing. Pavements were designed for a loading of 1CN 100.

Cost of project Rs. 3 million.

Other major projects—

NPK plants for Madras Fertilizers, Madras.

Phosphoric Acid Plant for Coromandel Fertilizers.

New Weaving Shed for Binny Mills.

Other Attainments—

Institution of Engineers, India.

Institution of Civil Engineers, London.

American Concrete Institute.

Committee on Planning and Design of Tall Buildings of ASCE and IABSE of America.

Practicing Engineers, Architects and Town Planners Association.

Examiner for M.E. Degree of Bombay University.

Member of several committees to investigate distress or failure of structures.

Member special committee of PEATA to formulate new code of practice for civil engineering profession in Bombay.

*Papers published—*Accelerated Curing Tests on Concrete Engineering of 21st February 1958 jointly with N. N. B. Ordman of Port of London Authority.

International Assignments—

Hotel Oberoi Soaltee at Kathmandu, Nepal.

Staging and foundations for Jatiroto and Semboro Sugar Plants in Indonesia.

Various Hangars for Qatar Armed Forces.

*Name—*R. G. Gandhi.

*Date of Birth—*5th January 1919.

*Education—*B.E. (Civil), Poona in 1942, Fellow of Institution of Engineers of India.

*Last post held (with designation and address or Organization)—*General Manager, The Hindustan Construction Company Limited, Construction House, Walchand Hirachand Marg, Ballard Estate, Bombay 400 038.

Permanent Address and Phone No.—'Panchsheel', Road No. 10, Juhu-Vile Parle Scheme, Bombay 400 049. Phone No. 576415.

Experience—

(A) *From 1st June 1968 to 1st June 1978—*General Manager of the Hindustan Construction Company Limited. The Chief Executive of the Company undertaking large projects in the country particularly in the field of Roads and Bridges, Irrigation, Power and Heavy Civil Engineering and Special Purpose Projects, like steel plants, water and sewage treatment plants. This is the oldest and biggest construction company in the private sector whose annual turnover reached Rs. 42 crores.

(B) *From 1st June 1961 to 1st June 1969—*Deputy General Manager working for the section of underground tunnelling works for Power and Irrigation Projects.

(C) *From 1st June 1959 to 1st June 1961—*Regional Manager, controlling works in two States, Gujarat and Maharashtra.

(D) *From 1st June 1955 to 1st December 1958—*Project Manager, Bhilai Steel Project, one of the three biggest steel plants, constructed in Second Plan period in record time of 30 months.

(E) *From 1st June 1949 to 1st June 1955—*Engineer in charge of various projects like (1) Delhi Thermal Power extension under Merz-McIlalan, consulting engineers, (2) Bombay Port Trust under sea pipe line project from Butcher Island to Trombay Refineries, (3) Reservoir projects for Military Engineering Service all over the State of Punjab.

Projects handled—

- (A) Idikki Power Project, Kerala where two dams are built in concrete.
- (B) Sabarimalai Power Project in Kerala.
- (C) Maneri Bhali Hydro-Electric Project at Uttar Kashi for U.P. Government having dam, tunnels and surface power house.
- (D) Yamuna Hydro-Electric Project with underground power station, dam, power tunnels, surge shaft and all ancillary works. First underground power station in Himalayas.
- (E) Sharavati Valley Power Projects, Karnatak, all the power tunnels, surge shaft and surface power house. This is the biggest Hydro-Power Station in the country.
- (F) Navamalai tunnel for Tamil Nadu Electricity Board in Tamil Nadu.
- (G) Silleru power tunnels for Andhra State Electricity Board.
- (H) Koyna underground power house and surge shafts and underground penstocks for Maharashtra Government.
- (I) D. B. K. Railway tunnels in Anantgiri Ghats of Andhra Pradesh for Southern Railway.
- (J) Bhadra tunnel and Malprabha tunnel works for irrigation in Karnatak.

Analysis of Relevant Experience Highlighting Specialisation—

(a) Management of large project employing expertise of all managements disciplines and techniques.

(b) The method of construction and planning of underground works, and the problems tackled in these works was unique. Unpredictable problems arise due to instability of rock formation methods used in stabilising these stratas have to be decided on the spot and new methods have to be innovated to meet these exigencies. To mention a few in Yamuna underground shot-crete was extensively used with quick setting compound to stabilise very bad Himalayan strata of rock; prestressed anchors were used to stabilise the abutments of the caverns of the underground power house. Special equipment was designed and fabricated to carry out work of surge shafts.

Countries visited and purpose—

- 1979 U.K. to attend International Conference of Acrow Engineers; U.S.A. and Canada to visit projects.
- 1978 All over Europe as a delegate nominated by Government of India to attend Conference sponsored by E.E.C. countries.
- 1974 U.K., France.
- 1970 U.S.A., Canada and Europe.
- 1968 Europe.
- 1954 Europe.
- 1949 France stayed six months to study complete Hydro Power Construction.

Membership of Professional Institutions—

- (1) Fellow of Institution of Engineers.
- (2) 1970-72 President, Builders' Association of India; Now Member of the Managing Committee.

Membership of International Government, Semi-Government and other Bodies or Panels—

Member of the Board of Directors of International Association of Housing Science, Florida, U.S.A.

Other positions being held now—

- (1) Director of Messrs. Indian Hume Pipe Company Limited, Bombay.
- (2) Chairman of Messrs. Acrow India Limited, Bombay.
- (3) Chairman of Messrs. Vikhroli Metal Fabricators Limited, Bombay.
- (4) Chairman of Messrs. GEM General Equipment Manufacturing Private Limited, Bombay.
- (5) Chairman of Messrs. Ganga Bridge Construction Company Limited, Bombay.
- (6) Director of Ajit Engineering Company Limited, Bombay.

Name—Mr. M. P. Gajapathy Rao.

Educational Qualifications—

- B.A. (Mathematics), Osmania University.
- B.E. (Civil), Madras University.
- Computer Programming FORTRAN IV—Datamatic Corporation, Bombay.

Appointments—

- (i) Research Assistant .. Central Water and Power Research Station, Pune. 1954-55
- (ii) Assistant Engineer, Class I, through the Hyderabad Public Service Commission (erstwhile). P.W.D., Government of Hyderabad. Allocated to (erstwhile) Bombay State P.W.D. on States Reorganisation in November 1956. Appointed in 1955. Successor Government : Government of Maharashtra, P.W.D.
- (iii) Executive Engineer (promoted as). P.W.D., Government of Maharashtra. January 1964
- (iv) Superintending Engineer (promoted as). P.W.D., Government of Maharashtra. January 1976.

Fields of Experience—

- (i) Road Projects,
- (ii) Bridge Projects,
- (iii) Highway Research,
- (iv) Structural Research,
- (v) Structural Designs:
 - (a) Multistoreyed Buildings
 - (b) Minor and Major Bridges
 - (c) Jetties
- (vi) Construction.

Merit Awards—

Total No. of Merit Awards : Five. Sixth under recommendation—

| <i>Award</i> | <i>By</i> | <i>Citation (Brief)</i> |
|-----------------------|-------------------------------|---|
| (1) Merit Certificate | .. Government of Maharashtra. | Meritorious technical Paper read in the Second Conference of the Buildings and Communications Department. |

| <i>Award</i> | <i>By</i> | <i>Citation (Brief)</i> |
|--|----------------------------|--|
| (ii) Merit Certificate | Government of Maharashtra. | (a) Creditably developing two Research Divisions, viz. Highway Research Division and Structural Research Division in the Maharashtra Engineering Research Institute. (b) Developing a technique of Precast and Prestressed Bridge Decks for Spillway bridges which has resulted in hitherto unknown construction speeds advancing Irrigation benefits. (c) Designing and developing Electronic strain and Pressure Gauges. |
| (iii) Incentive Allowance .. | Government of Maharashtra. | For Precast Prestressed Bridge Decks for Spillway bridges. |
| (iv) Merit Certificate .. | Government of Maharashtra. | Technical paper read at the Third Conference of Engineers of the Public Works Department. |
| (v) Merit Certificate .. | Government of Maharashtra. | Construction in the Planning and Design of the Bridge Project across Godavary River in Nanded. |
| (vi) Merit Certificate (under recommendation). | Government of Maharashtra. | Design of the New Council Hall, Bombay. |

Membership on All-India Professional Bodies—

| | |
|-----------------|---|
| (i) Member .. | Indian Roads Congress. |
| (ii) Member .. | Bridge Committee, Indian Roads Congress. |
| (iii) Member .. | Cement and Concrete Sectional Committee, BDC 2, Indian Standards Institution. |
| (iv) Member .. | Foundations Committee, BDC 13 p-1, Indian Standards Institution. |

Membership on State Government Technical Committees/Study Groups (Past)—

| | |
|----------------------------|---|
| (i) Convener .. | Study Group on R.C.C. Techniques in New Council Hall Project. |
| (ii) Member-Secretary .. | Technical Committee for Reviewing the Tapi Bridge Project, Dhule District. |
| (iii) Member .. | Committee for Model Studies to assess the effects of reclamation in Bandra-Kurla Complex—Engineering Feasibility Studies. |
| (iv) Member .. | Steering Committee for Highway Research. |
| (v) Member .. | Implementation Group for New Council Hall, Bombay. |
| (vi) Member .. | Study Group on Use of Electronic Digital Computer in P.W.D. |
| (vii) Convener .. | Committee for Bridge across Katepurna River. |
| (viii) Member-Secretary .. | Committee for Techno-Economic Feasibility Studies of the Bombay-Uran Link. |

Publications—

| <i>Paper</i> | <i>Journal</i> |
|---|--|
| (i) Design Co-efficients for Box Type of Bridge Returns. | Indian and Eastern Engineer. |
| (ii) Thane Creek Bridge | Maharashtra Public Works Journal. |
| (iii) Effect of Koyna Earthquake on Bridges in the Region. | Journal of International Association of Bridge and Structural Engineers (Indian National Group). |
| (iv) Experiences on Bridge Projects in the State. | Maharashtra Public Works Journal. |
| (v) Partially Prestressed Precast Bridge Decks for Spillway Bridges. | Conference of Engineers of the B. and C. Department. |
| (vi) Lime-Flyash-Soil stabilised Road Sub-basis. | Annual Session of Central Board of Irrigation and Power. |
| (vii) Joints in Precast structural Members | Annual Session of Central Board of Irrigation and Power. |
| (viii) Ultimate strength design and partial prestressing in Bridges. | Conference of Engineers of P.W.D. |
| (ix) Specifications for R.C.C. and Prestressed Concrete Structures in Marine Environment. | Conference of Engineers of P.W.D. |
| (x) Guidelines for Design and Construction of C.D. Works and Bridges in the State. | Technical Circular Designs Circle, P.W.D. |

APPENDIX 'E'

List of Counsel

- | | | |
|-----------------------------------|----|--|
| (1) Mr. V. P. Tipnis, Advocate | .. | Model Construction Company. |
| (2) Mr. S. G. Mandrekar, Advocate | } | .. Municipal Corporation of Greater Bombay |
| (3) Miss S. V. Senjit, Advocate | | |
| (4) Mr. M. B. Rele, Advocate | } | .. Commission of Inquiry. |
| (5) Mr. G. N. Kini, Advocate | | |

APPENDIX 'F'

M-EXHIBITS

Documents produced by the Bombay Municipal Corporation and exhibited in the Proceedings

| Description of Documents | M. Exhibit No. | No. of Documents | Date on which tendered | No. of pages |
|---|----------------|------------------|------------------------|------------------------------|
| 1 | 2 | 3 | 4 | 5 |
| Cement Register No. 1 | M-1 | 1 | 14-4-1981 | 51 (and 2 loose sheets) |
| Cement Register No. 2 | M-2 | 1 | 14-4-1981 | 51 |
| Measurement Book No. 1 | M-3 | 1 | 14-4-1981 | 101 |
| Measurement Book No. 2 | M-4 | 1 | 14-4-1981 | 87 |
| Measurement Book No. 3 | M-5 | 1 | 14-4-1981 | 16 |
| Pile Record Register No. 1 | M-6 | 1 | 14-4-1981 | 100 |
| Pile Record Register No. 2 | M-7 | 1 | 14-4-1981 | 86 |
| Steel Register | M-8 | 1 | 14-4-1981 | 114 (and 13 loose papers) |
| Steel Supply (supplied by M.C.G.B.) Register. | M-9 | 1 | 14-4-1981 | 1 |
| Cube Register | M-10 | 1 | 14-4-1981 | 8 |
| Progress Register No. 1 | M-11 | 1 | 14-4-1981 | 172 |
| Progress Register No. 2 | M-12 | 1 | 14-4-1981 | 67 |
| Monthly Cement Consumption Register.. | M-13 | 1 | 14-4-1981 | 134 |
| Instructions Book | M-14 | 1 | 14-4-1981 | 9 |
| Triplicate Books | M-15A | 1 | 14-4-1981 | 4 |
| | M-15B | 1 | 14-4-1981 | 17 |
| | M-15C | 1 | 14-4-1981 | 99 |
| Cable Stressing Register (Note Book) .. | M-16 | 1 | 14-4-1981 | 7 |
| Details of Prestressed Girder (Note Book) | M-17 | 1 | 14-4-1981 | 48 |
| Register of Cement Consumption with Percentage Variation (Note Book). | M-18 | 1 | 14-4-1981 | 168 |
| Ghani Registers | M-19A | 1 | 14-4-1981 | 48 |
| | M-19B | 1 | 14-4-1981 | 68 |
| | M-19C | 1 | 14-4-1981 | 168 |
| | M-19D | 1 | 14-4-1981 | 80 |
| | M-19E | 1 | 14-4-1981 | 92 |
| | M-19F | 1 | 14-4-1981 | 90 |
| | M-19G | 1 | 14-4-1981 | 84 |
| | M-19H | 1 | 14-4-1981 | 170 |
| | M-19I | 1 | 14-4-1981 | 38 |
| | M-19J | 1 | 14-4-1981 | 88 |
| Test Report Files | M-20A | 1 | 14-4-1981 | 286 |
| | M-20B | 1 | 14-4-1981 | 26 |
| Office Correspondence File No. 1 | M-21 | 1 | 14-4-1981 | 113 |
| Site Correspondence File No. 2 | M-22 | 1 | 14-4-1981 | 105 |
| Cement Statement File | M-23 | 1 | 14-4-1981 | 79 |
| Steel Receipts File | M-24 | 1 | 14-4-1981 | 68 |
| Recovery Statement (<i>Ad hoc</i> Bills) File .. | M-25 | 1 | 14-4-1981 | 42 |

| Description of Documents | M. Exhibit No. | No. of Documents | Date on which tendered | No. of pages |
|--|----------------|---------------------------|------------------------|---------------------|
| 1 | 2 | 3 | 4 | 5 |
| File containing Approved Drawings with Index. | M-25A to M-26S | 19 | 14-4-1981 | |
| Steel Indent Book (Indent Nos. 02351 to 02400). | M-27 | 1 | 14-4-1981 | 19 |
| Silt Register, Asphalt Macadam and Removal. | M-28 | 1 | 14-4-1981 | 6 |
| Earth Removal Challan File .. | M-29 | 1 | 14-4-1981 | 85 |
| Cement Challans File .. | M-30 | 1 | 14-4-1981 | (Challans) 147 |
| Asphalt Challans File .. | M-31 | 1 | 14-4-1981 | (Challans) 59 |
| Triplicate Books .. | M-32A | 1 | 14-4-1981 | (Challans) 100 |
| | M-32B | 1 | 14-4-1981 | 100 (1 loose paper) |
| | M-32C | 1 | 14-4-1981 | 100 (1 loose paper) |
| | M-32D | 1 | 14-4-1981 | 100 |
| Removal Challans Books .. | M-33A | 1 | 14-4-1981 | 100 (Challans) |
| | M-33B(i) | 1 | 14-4-1981 | 55 (Challans) |
| | M-33B(ii) | | 14-4-1981 | 42 (Loose Challans) |
| Original Tender submitted by the Contractor. | M-34 | 1 | 14-4-1981 | 157 |
| Original Contract .. | M-35 | 1 | 14-4-1981 | 114 |
| Exercise Book containing Design Mix prepared by Shri Thorat. | M-36 | 1 | 14-4-1981 | 36 |
| Reports from the Testing Laboratory, dated 5th and 22nd September 1980 regarding test of concrete prestressed girders. | M-37A | 1 | 14-4-1981 | 1 |
| | M-37B | 1 | 14-4-1981 | 1 |
| Approved Drawings containing three drawings for prestressed girders and 3 drawings for centering. | M-38 | 2 (Sets) | 14-4-1981 | |
| Photographs taken after collapse of girders on 30th September 1980. | M-39 | 10 (Nos.) | 14-4-1981 | |
| Copy of list of Consultants for Bridges .. | M-40 | 1 | 14-4-1981 | 1 |
| Photographs taken immediately after the collapse of girders as well as on 3rd March 1981 with negatives numbering 25. | M-41 | 1 (Set of 23 Photographs) | | |
| Drawings No. 7A showing the details of portal frame, foundation etc. for the prestressed span. | M-42 | 10 (Sets) | 14-4-1981 | |
| Cable Extension Chart | M-43 | 6 (Sets) | 14-4-1981 | |

| Description of Documents | M. Exhibit No. | No. of Documents | Date on which tendered | No. of pages |
|--|----------------|------------------|------------------------|--------------|
| 1 | 2 | 3 | 4 | 5 |
| Empty Cement Paper Bag .. | M-44 | 1 | 14-4-1981 | |
| Ghani Registers in respect of Lalbaug Flyover. | M-45A | 1 | 14-4-1981 | 83 |
| | M-45B | 1 | 14-4-1981 | 89 |
| | M-45C | 1 | 14-4-1981 | 74 |
| | M-45E | 1 | 14-4-1981 | 84 |
| | M-45E | 1 | 14-4-1981 | 98 |
| | M-45F | 1 | 14-4-1981 | 83 |
| | M-45G | 1 | 14-4-1981 | 74 |
| | M-45H | 1 | 14-4-1981 | 76 |
| | M-45I | 1 | 14-4-1981 | 83 |
| | M-45J | 1 | 14-4-1981 | 60 |
| Cable Stressing Register-I in respect of Lalbaug Flyover (Note Book). | M-46 | 1 | 14-4-1981 | 67 |
| Stressing Record-II for Lalbaug Flyover (File). | M-45 | 1 | 14-4-1981 | 82 |
| Silt Register for Lalbaug Flyover (Note Book). | M-48 | 1 | 14-4-1981 | 8 |
| Site Muster for the months of August, September, October, November, December 1980. | M-49 | | 27-4-1981 | 20 |
| Rough Book | M-50 | | 27-4-1981 | 13 |
| General Conditions of Contract for Civil Works. | M-51 | | 27-4-1981 | 67 |
| Copy of Plan showing details of the collapsed girders. | M-52 | | 22-5-1981 | |
| Drawing showing actual levels. .. | M-53 | | 22-5-1981 | |
| Copies of letters, dated 13th September 1979 written by Deputy City Engineer (Project) to Western and Central Railways about the supply of steel cribs and copies of replies, dated 22nd September 1979 by the Central and Western Railways. | M-54 | | 26-5-1981 | 3 |
| Office copy of the letter, dated 5th October 1979 addressed to Messrs. Model Construction Co. by Deputy City Engineer. | M-55 | | 26-5-1981 | |
| Plan showing location of 4 P.S.C. girders. | M-38A | | 29-5-1981 | |
| Steel Crib arrangement for supporting P.S.C. girders 36.014 span. | M-38B | | 29-5-1981 | |
| Details of P.S.C. girder for straight span, span 35755 c/c. | M-38C | | 29-5-1981 | |
| Details of R.C.C. girder steel and block, Articulation Diaphragm, kerb, Dec. Slab etc. (Drawing No. MC/Byc/18, dated 21st November 1977). | M-38D | | 29-5-1981 | |
| Details of super structural straight span (Drawing No. MC/Byc/18, dated 21st November 1977). | M-38E | | 29-5-1981 | |
| General arrangement of form work for casting P.S.C. girder span 36.80 c/c. Details of wooden frame and Battens. | M-38F | | 29-5-1981 | |
| Six Pert Charts in respect of the work of Flyover at Gloria Church, Byculla. | M-56 | | 17-6-1981 | |

APPENDIX ' G '
CONTRACTORS' EXHIBITS

Documents produced by the contractors and exhibited in the proceedings

| Description of Documents | Con. Exhibit No. | No. of Documents | Date on which tendered | No. of pages |
|---|------------------------|---------------------|------------------------------|-----------------|
| 1 | 2 | 3 | 4 | 5 |
| Application on behalf of Contractors .. | CON-1 | 1 | 3-4-1981 | 1 |
| Publications regarding qualifications of Mr. Diwan. | CON-2 | 1 | 8-6-1981 | 5 |
| Pert Chart (Plan) .. | CON-3 | 1 | 8-6-1981 | 1 |
| Draft Guidelines on designs for Roads and Bridges and order of formwork prepared by Indian Road Congress. | CON-4 | 1 | 8-6-1981 | 48 |
| Calculations about the Crib Stool Support at the ends of Girder No. 1. | CON-5 | 1 | 8-6-1981 | 2 |
| The Design Calculations consisting of 60 sheets. | CON-6 | 60 | 12-6-1981 | 60 (Sheets) |
| Two Drawings—one showing the manner of collapse of the two girders and the other showing the position of the two girders after the collapse. | CON-7 | 2 | 15-6-1981 | 2 (Drawings) |
| Original Agreement, dated 1st December 1976 between Mr. Diwan and Messrs. Model Construction Co. (True Copy taken on record). | CON-8 | 1(2) | 17-6-1981 | 2 |
| A Diagram showing dispersion of load on all the three panels drawn by Mr. Diwan. | CON-9 | 1 | 17-6-1981 | 1 |
| Copy of Pert Chart produced by witness Mr. Diwan bearing his signature and copy of letter, dated 2nd July 1980. | CON-10 | 1 | 22-6-1981 | 2 (1 Chart) |
| Copy of letter, dated 21st October 1980, written by Messrs. Model Construction Company to Senior Divisional Engineer, Metropolitan Transport Project, Churghate in respect of Flyover Bridge, Bandra. | CON-11 | 1 | 23-6-1981 | 1 |
| Tentative Programme for balance works at Byculla. | CON-12 | 1 | 23-6-1981 | (1 Chart) |

APPENDIX 'H'
COMMISSION'S EXHIBITS

Documents produced by the Commission and exhibited in the proceedings

| Description of Documents | C. Exhibit No. | No. of Documents | Date on which tendered | No. of pages |
|--|----------------------|---------------------|------------------------------|-----------------|
| 1 | 2 | 3 | 4 | 5 |
| Letter, dated 6th April 1981 by Dr. Shirish Patel. | C-1 | 1 | 14-4-1981 | 1 |
| Order, dated 14th April 1981 on the application of Mr. Tipnis, Advocate for Contractors. | C-2 | 1 | 14-4-1981 | 2 |
| Points for consideration | C-3 | 1 | 27-4-1981 | 2 |
| Notes of Site Inspection Nos. I, II, III and IV, dated 3rd March 1981, 11th March 1981, 17th March 1981 and 24th March 1981 respectively. | C-4 | | 22-5-1981 | 10 |
| Letter No. 1041/81, dated 7th May 1981 and letter No. 1071/81, dated 11th May 1981 from the Assistant Commissioner of Police, Girgaon Division, Bombay containing his report u/s 5-A of the Commission of Inquiry Act together with the statement of Salamat N. Irani, dated 11th May 1981 and 7th May 1981; Kirit M. Desai, dated 1st October 1981; Ghansham Vithal Paranjpe, dated 11th October 1981; Jokhal s/o Ramnath Mistry, dated 30th September 1980; and two panchanamas, dated 1st October 1980. | C-5 | | 22-5-1981 | 9 |
| Report, dated 10th May 1981 (10 pages) of panel of Experts appointed by the Commission to investigate causes of collapse with Annexures. | C-6 | | 22-5-1981 | 10 |
| Letter, dated 19th May 1981 signed by the members of the panel. | C-6A | 1 | 22-5-1981 | 1 |
| List of relevant documents seen by the panel. | C-6B | | 22-5-1981 | 23 |
| Survey and Record of materials found at site. | C-6C | | 22-5-1981 | 9 |

| Description of Documents | C. Exhibit No. | No. of Documents | Date on which tendered | No. of pages |
|--|----------------|---------------------|------------------------|-----------------------------|
| 1 | 2 | 3 | 4 | 5 |
| A Questionnaire sent by the Commission to the engineers concerned with the construction of the Bridge and answers thereto. | C-6D | | 22-5-1981 | 6 |
| Design Calculation of the Temporary Structures. | C-6E | | 22-5-1981 | 8 |
| Test Report of the materials used .. | C-6F | | 22-5-1981 | 13 |
| Meteorological Report .. | C-6G | | 22-5-1981 | 5 |
| The Record of the final levels of the portal. | C-6H | | 22-5-1981 | 2 |
| Test of random samples of timber sleepers. | C-6I | | 22-5-1981 | 4 |
| Drawing showing measures taken for stabilisation of tilt of prestressed Girder No. 1. | C-6J | | 22-5-1981 | 1 |
| Rough sketch drawn by M.W. No. 2 of Girders Nos. 1 and 2. | C-7 | 1 | 27-5-1981 | 1 |
| Report submitted by Mr. M. P. Gajapathy Rao appointed by the Commission under Section 5-A on 1st June 1981. | C-8 | 1 | 2-6-1981 | 56 (including Annexures) |
| Acrow prop publication by Acrow India Ltd. | C-9 | 1 | 2-6-1981 | 14 |
| Sketch drawn by M. W. No. 5 Mr. Palshetkar of the stressing of the cables. | C-10 | 1 | 4-6-1981 | 1 |
| Copy of letter No. CE/492/Project, dated 16th April 1981 from the Deputy City Engineer to the Secretary to the Commission. | C-11 | 1 | 17-6-1981 | 1 |
| Bio-Data of Dr. Gupchup .. | C-12 | | | 7 |
| Eighteen Photographs .. | C-13 | 18 (Photographs) | | |
| Calculations made by Dr. Gupchup in respect of load carrying capacity of all the eight props in the Crib Steel System. | C-14 | | | 1 |
| Notes comprising of 4 sheets in respect of visit to the Site. | C-15 | | | 4 |

APPENDIX 'I'

List of Drawings

| Serial No. | Exhibit No. | Subject | Date of Drawing | Drawing No. | Date of Letter of Approval |
|------------|-------------|--|-----------------|--------------|-------------------------------------|
| 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | M-26A | Details of R.C.C. return wall at North Approach .. | Nil | MC/BYC/14 | 14-3- (Letter No. 6444) |
| 2 | M-26B | Details of R.C.C. Pile Caps, Columns, tie beams and pedestals for 36.08 M. Prestressed Span. | 17-11-1977 | MC/BYC/07A | (Letter No. 5882) |
| 3 | M-26C | Details of R.C.C. Girder Steel, End Block, Articulation, Diaphragms, Kerb, Deck Slab. | 28-11-1977 | Nil | 3-1-1979 |
| 4 | M-26D | 'L' Section, details of spans and solid approaches with relevant levels. | 16-6-1977 | MC/BYC/04(R) | Nil |
| 5 | M-26B | Details of R.C.C. pile and pile cap under 10.97 metres span. | Nil | MC/BYC/06A | 20-10- (Letter No. 3251) |
| 6 | M-26F | Details of pile layout for abutment and return at south end. | Nil | MC/BYC/10 | (Letter No. 4886) |
| 7 | M-26G | Details of 525 R.C.C. pile and pile cap under 10.97 metres span. | 3-10-1977 | MC/BYC/06 | 7-10- (Letter No. 2730) |
| 8 | M-26H | R.C.C. Columns and Beam 10.97 metres span .. | 3-11-1977 | MC/BYC/07 | 4-11- (Letter No. 3791) |
| 9 | M-26I | R.C.C. Details of pile cap for abutment and return at south approach. | Nil | MC/BYC/12 | (Letter No. 11559) |
| 10 | M-26J | Details of North Abutment | 17-3-1978 | MC/BYC/13 | (Letter No. 6444) |
| 11 | M-26K | 'L' Section. Details of Span and Solid Approaches with relevant levels. | 16-6-1977 | MC/BYC/04(R) | No date of approval. 4-1-1978 |
| 12 | M-26L | Details of abutment and return at South Approach .. | Nil | MC/BYC/11 | (Letter No. 11559) |
| 13 | M-26M | Details of R.C.C. Girder, Steel, End Block, Articulation, Diaphragms, Kerb, Deck Slab etc. for curve span. | Nil | Nil | (Letter No. 2470) |
| 14 | M-26N | Details of superstructure straight span | 21-11-1977 | MC/BYC/18 | (Letter No. 414) |
| 15 | M-26O | Details of deck slab for R.C.C. 19.97 span .. | Nil | MC/BYC/09 | 10-5- 4-12- (Letter No. 4535) |
| 16 | M-26P | Details of Prestressed Concrete Girder for straight span. | 25-11-1977 | MC/BYC/16 | 10-5-1979 (Letter No. 414) |

| Serial No. | Exhibit No. | Subject | Date of Drawing | Drawing No. | Date of Letter ¹ of Approval |
|------------|-------------|--|-----------------|-------------|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
| 17 | M-26Q | Details of Prestressed Concrete Girder, End-block, Articulation, Diagrams, Kerb, Deck Slab, etc. | 28-11-1977 | MC/BYC/17 | 10-5-1979 (Letter No. 414) |
| 18 | M-26R | Details of super structure for curve span .. | Nil | Nil | 3-9-1979 (Letter No. 2470) |
| 19 | M-26S | Details of Prestressed Concrete Girder for curved span 35755 c/c of bearing. | Nil | Nil | 19-2- (Letter No. 2470) |
| 20 | M-38A | Arrangement of casting P.S.C. Girder and lowering in position. | Nil | MC/BYC/Nil | Nil |
| 21 | M-38B | Steel Crib arrangement for supporting P.S.C. Girder, 36.0 m. span. | Nil | Nil | Nil |
| 22 | M-38C | Details of P.S.C. Girder for straight span—Span 35755 c/c of bearing. | 25-11-1977 | MC/BYC/16 | Nil |
| 23 | M-38D | Details of R.C.C. Girder Steel, End Block, Articulation, Diagrams, Kerb, Deck Slab etc. | 28-11-1977 | MC/BYC/17 | Nil |
| 24 | M-38E | Details of superstructure straight span | 21-11-1977 | MC/BYC/18 | Nil |
| 25 | M-38F | General arrangement of form work for casing P.S.C. Girder Span 36-80 c/c. Details of wooden frame and battons. | Nil | Nil | Nil |
| 26 | M-43 | Cable Extension Chart | Nil | Nil | Nil |

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