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Picture credits: Bottom: Rescue 1122; Top inset: Still from Security Camera

M2 Motorway, Pakistan, Salt Range, Potohar Plateau, Kallar Kahar
Islamabad-Jhang Bus Meets Accident, 17th June, 2023

The Pakistan
Civil Engineer

Pakistan Society of Civil Engineers

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Editorial

The current issue of the Pakistan Civil Engineer is in front of you.

The issue has a focus on transportation engineering and this focus was triggered by the most painful bus accident of 17th June, 2023 on M2, in the Kallar Kahar area. This area has become a type of Bermuda triangle for vehicles, where accidents have become a matter of routine. It is a challenge for the transportation engineers of the country – a challenge that must be addressed.

I invite all specialists to contribute and help prepare a considered document that may be forwarded to the concerned authorities and perhaps also released to the press for helping it build an informed opinion.

As may be noticed, we are short of contributions, like always. This requires help from each reader.

Looking forward to feedback from the readers,

Rizwan Mirza

Rizwan Mirza, CE
Editor-in-chief

Cover Story

Travelling Dangerously

Rizwan Mirza
Editor-in-chief

Introduction

Pakistan's famous Lahore-Islamabad motorway, M-2, traverses through a short curvilinear stretch, of a few kilometres, marked by horizontal curves of relatively small radii and rather steep gradient, characteristic of a hilly area.

Figure 1: An overall view of the red zone

The horizontal geometry comprises circular compound curves and vertical geometry is characterised by steep gradients, with radii of the order of 86 m, and gradients as steep as seven percent. The distance from S222 and S231 is a 10 odd kilo meters.

There is a speed limit of 30 km/hr for HTV's and 50 km/hr for LTVs, as against the normal speed limits of 110 km/hr and 120 km/hr, respectively.

Figure 2: A speed-limit sign

Motorways are entry and exit-controlled highways with strict loading regulations. Speed is controlled, in case of public transport vehicles, through a system of tickets issued at entry and checked at the exit.

Additionally, entry of animals, humans and animal-driven vehicles is not allowed. There are no level crossings anywhere.

Figure 3: A sharp turns warning sign

Historical Background

We see history repeating itself, here. The short stretch of the motorway, plagued by sharp and steep turns, has continued to cause accidents.

Statistics available to the author reveal that the zone in question and particularly two turns alone, have caused a significant number of accidents in the past.

"This is not the first accident and, God forbid, may not be the last, if the situation remains unchanged."

Figure 4: A view of a curve in the red zone

Figure 5: Median barrier of motorway

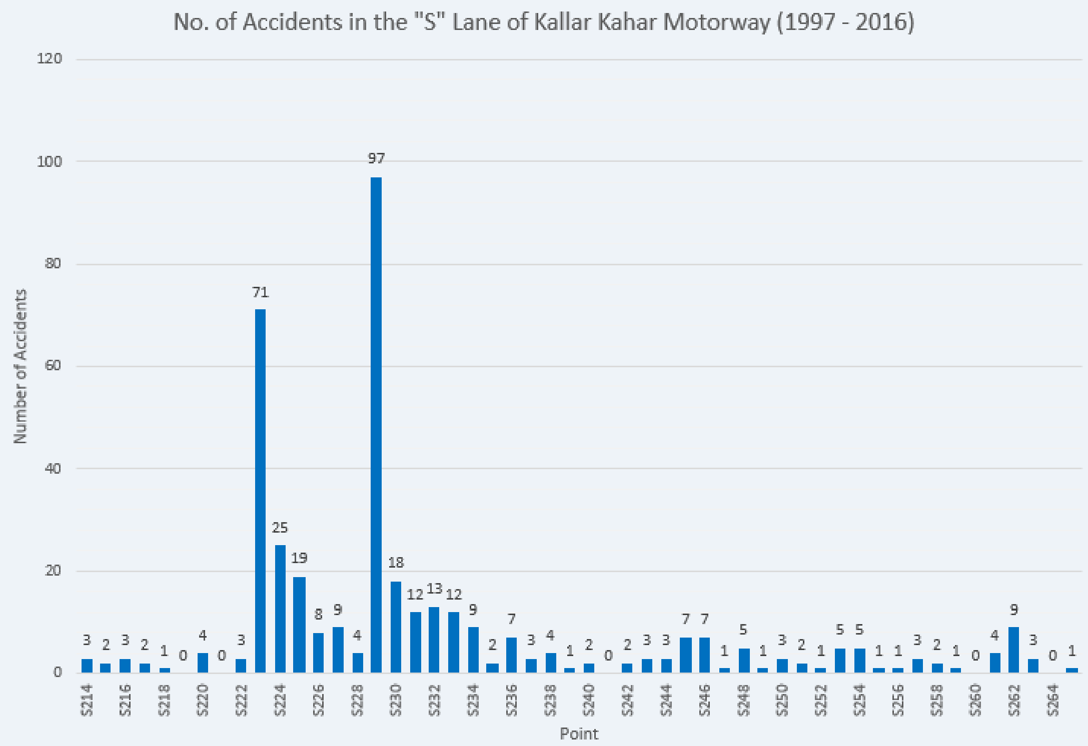

Figure 6: Number of accidents at various points during a period of around two decades

As may be noted, there have been 97 (24.01%) and 71 (17.57%) accidents at points S229 and S223, respectively during the period of 1997 to 2016.

> ***"We may, therefore, conclude that two locations, together, account for 41.58% of accidents. "***

Further investigation reveals that 56.93% accidents are caused by 5 locations, alone. A detailed graphical representation has been attached below:

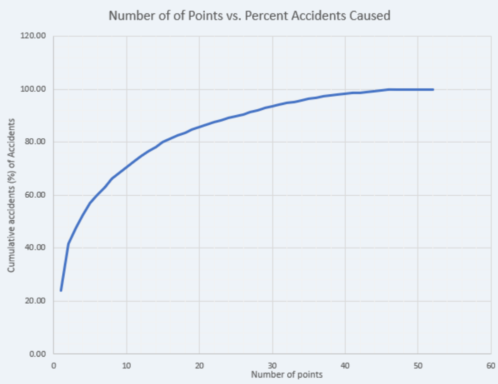

Figure 7: Number of Points vs. Percent Accidents

Most of the past accidents have been single-vehicle events.

The 17th June, 2023 Kallar Kahar Accident

On the fateful day of 17th June, 2023, a bus starting its journey at Rawalpindi and bound for Jhang entered this difficult area of M2 and rolled over, at 10:12 am, reportedly leaving some 13 killed and 15 injured.

The accident took place approximately 133 km from Islamabad, on the 184 km long motorway.

Motorway police is reported to have said that a brake failure was the cause of the accident. The author is not privy to the scientific basis of this inference.

Frame-by-frame Analysis

Following are selected still frames obtained from a video from a CCTV camera, that captured the accident:

Frame-01

Time: 10:12:56 am; Bus appears within the camera

Figure 8: Frame-01

Frame-02

Time: 10:12:56 am; Bus moves forward, rear left wheels already lifted through a rotation around the longitudinal axis.

Figure 9: Frame-02, Time: 10:12:56 am

Frame-03

Time: 10:12:57 am; Bus moves forward, rear left wheels lifted through a further rotation around the longitudinal axis.

Figure 10: Frame-03

Frame-04

Time: 10:12:57 am; Bus moves forward, Rear left wheels lifted further through a greater rotation around the longitudinal axis. Irrecoverable instability has taken place.

Figure 11: Frame-04

Frame-05

Time: 10:12:57 am; Bus completely overturned and crashed against the barrier.

Figure 12: Frame-05

Frame-06

Time: 10:12:58 am; Bus completely overturned by having rotating around its longitudinal axis by 90°, is now sideways, over the barrier.

Figure 13: Frame-06

Frame-07

Time: 10:12:58 am; Bus further rotates around its longitudinal axis, beyond 90° now, with its top hitting the road from the opposite side.

Figure 14: Frame-07

Frame-08

Time: 10:12:58 am; Bus has rotated around its transverse axis by around 30°.

Figure 15: Frame-08

Frame-09

Time: 10:12:58 am; Bus has rotated around its transverse axis by around 45°.

Figure 16: Frame-09

Frame-10

Time: 10:12:59 am; Bus has rotated around its transverse axis by around 90°.

Figure 17: Frame-10

Frame-11

Time: 10:12:59 am; Bus has rotated around its transverse axis by around 95° and has drifted away from the barrier.

Figure 18: Frame-11

Frame-12

Time: 10:12:59 am; Bus has rotated around its transverse axis by around 95° and has drifted further away from the barrier.

Figure 19: Frame-12

Frame-13

10:13:00 am; Bus has rotated around its transverse axis by around 95° and has drifted still further away from the barrier.

Figure 20: Frame-13

Frame-14

10:13:05 am; Bus has come to a halt and a car, coming from the opposite side, is seen in an upside-down position.

Figure 21: Frame-14

Discussion of Bus Movement

Following points, noticed during the examination of frames, merit attention:

1. A median barrier has been provided and the width of the median is small.

2. A truck is seen moving, in the middle lane, slightly ahead of the bus and remains visible – albeit partially so – till frame 13, maintaining the same distance from the bus. There is, therefore, a very good reason to believe that both the vehicles were moving at nearly the same speed.

3. The loss of control and rotation to an unbalance condition is noticeable in the very first frame.

4. Within 1 second of appearance in the camera, the bus had undergone an irrecoverable loss of balance.

5. A cross-median collision takes place at the end.

A median barrier has been provided probably because the width of the median is small and traffic volume is not considered low.

The author does not have access to the testimonies of the survivors nor to the experts who have physically examined the bus. As such, nothing can be said with certainty, as to the real cause of the accident.

Figure 22: the deputy commissioner Chakwal, inquiring after the condition of the injured

Causes of Highway Accidents

Highway accidents may be caused by one more of the factors enumerated in the following non-exhaustive list:

1. Inferior vehicle design or maintenance

2. Inferior highway design or maintenance

3. Driver error

4. Poor weather conditions

5. Inferior rules governing vehicle safety

Vehicles with higher centre of gravity are statistically more likely to undergo rollover.

"There is often no single cause of a highway accident. Multiplicity of factors involved suggest that a highway accident is often a failure of the system. "

Hilly Terrain Issues

There are some key issues that need to be addressed while designing a highway in a hilly terrain. Most of these factors relate to geometrics.

1. In order to keep the gradients within code limits, designers often resort to increasing the length of road by adding curvilinear paths.

2. In certain cases – but not always – bridges and tunnels may be added in order to reduce the number of curves. But these features add to the capital cost of he project

3. Codes do permit sharp grades in hilly areas, but set an upper limit on them.

4. Visibility issues also need to be addressed when approaching blind turns.

5. In all highway projects, as also with some others, land-acquisition is an issue to be addressed.

The Future

Press reports state that the authorities have taken the following steps so far:

1. Criminal proceedings have been started against the operator, its officials and perhaps also against some government officials.

2. A decision has been made that a government official would travel in each bus in future.

The first step shall be taken only when ingredients of crime are present in a matter. This is to say that *Actus Reus* must be accompanied by *Mens Rea*., if criminal charges are to be pressed; otherwise it would be construed as an attempt to avoid the main issue.

Besides, such actions are well-known bureaucratic tools for appeasement of citizens, reducing political pressure and a means to avoid addressing the real underlying causes, such as its own faults.

"It shall be noted that the overriding objective of identifying the "offender" overshadows the actual technical and professional requirements of the investigation of an accident."

The second step appears to be of marginal utility only as, if anything, an accompanying official can only increase the stress of the driver.

The author recommends the following, in order to reduce the number of accidents:

1. Large projects shall be very carefully designed by experienced professional without any bureaucratic or political interference. Projects shall be planned and designed well ahead of the implementation time so that there is no undue haste involved.

2. Design of locations showing statistical evidence of repetitive accidents shall be revisited and intervention made, if required.

3. Involvement of duly trained transportation engineers, in lead positions, in the design and documentation phases, construction phases, overall project management and post-construction management of all transportation projects.

4. Drivers shall be duly trained, experienced and familiar with the area – if it is known to be unusual – and not be allowed to work under fatigue or distraction.

5. Each accident shall be professionally investigated in an uninterested and impartial manner, considering all aspects involved. Qualified and duly trained transportation as well mechanical engineers shall lead the investigation team.

6. Design width of medians may need to be revisited. When the medians are small in width, very little room for manoeuvring is left with the driver.

7. With high level of headlights, median barriers do not prevent headlight glare from effecting the drivers approaching from the opposite side, during night-time.

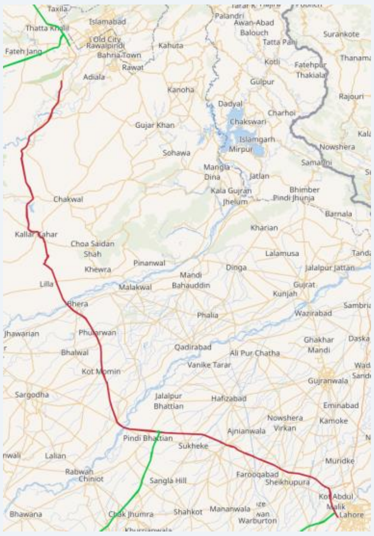

Figure 23: Route Map of Motorway M2

Acknowledgement: The author gratefully acknowledges the valuable input from Mr Sohail Raza and Mr Azhar Ali Bhatty for by way of review and valuable comments, before finalisation of the articles.

Masonry Infill Panels in Reinforced Concrete Frames

Rehan Wain, P.E. USA, P.E. Pakistan[1]

Introduction

Masonry infill panels in reinforced concrete are snug-fit masonry walls, intended to be non-load bearing, but in full contact with the slabs, beams (if present) and columns.

Little used in developed countries, such panels are commonplace in our country and some others in our part of the world, such as India, Sri Lanka, Nepal and Bhutan.

Some of the reasons for their wide acceptability are as follows:

1. Lack of availability of many cladding options
2. Social grounds
3. Wide availability of masonry units
4. Inertia of tradition

Masonry walls have greater bulk density than soft partitions and, therefore, increase the gravity load on the system.

A comparison between brick masonry walls and light-gauge framed walls is presented below:

Property	Brick Wall	Light gauge Framed Wall
Weight	80 to 100 psf (9" thick)	15 to 18 psf
Construction time	Slow	Fast
Material cost	Low	High
Acoustic insulation	Good	Low

Effect on Structural Behaviour

The infill panels automatically interact with the reinforced concrete frame in transmission of gravity as well as lateral loads. It is obvious that the panels are load as the frame deforms.

Following are the effects on their presence on structural action:

1. Increase in the stiffness and consequent reduction in time period of vibration.
2. Modification of the assumed distribution loading on various plane frames due to the presence or absence of the panels in each.
3. Masonry, having very nominal tensile strength, the panels provide diagonal struts of one orientation as the lateral load moves the structure in one direction and provide diagonals struts of the opposite orientation, as the lateral load reverses its direction. The diagonals expected to carry tension, in fact, go out of action, during each such movement.
4. As the capacity of panels is exhausted during lateral shaking, the panels go completely out of action.
5. The presence of panels in particular plane frames increases their stiffness and such plane frames attract greater lateral force than they would have without the presence of said panels.
6. The panels start sharing the gravity loads as the beam-slab horizontal sub-system deforms and thus alter the load-transmission path.

[1] MS Structural Engineering, University of California, San Diego; CEO Axform

Choices During Structural Analysis

The author feels that the designer theoretically has only two broad rational choices, while analysing buildings with infill masonry panels:

1. Isolate the panels by maintaining a distance between them and the frame and proceed with the analysis completing ignoring their presence.

2. Keep the panels snug-fit and perform a step by step non-linear analysis with compression-only diagonals and finally taking the diagonals out as they exhaust their capacity.

Ignoring the presence of snug-fit panels during the structural analysis is not an available rational choice.

The following figured demonstrates the diagonal strut action of infill panels:

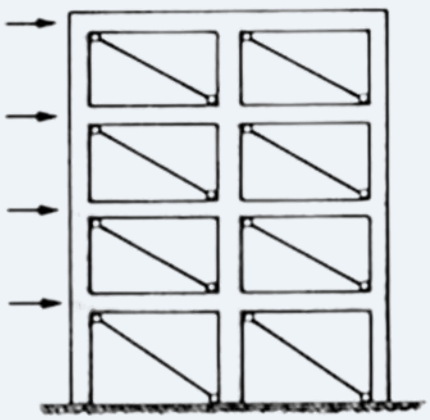

Figure 24: The concept of diagonal struts

Effect on Base Shear

Equivalent Static Analysis

In case of the use of equivalent static analysis, the overestimation of fundamental period of vibration would result in underestimation of the base shear.

Response Spectrum Analysis

In case of the use of response spectrum analysis, the outcome would have three possibilities, as is evident from the shape of following code-base idealised response-spectrum:

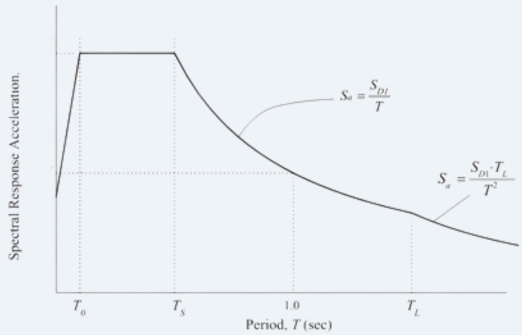

Figure 25: ASCE-7 Idealised Response Spectrum

The RS has three distinct parts: a) the ascending part; b) the flat part; and c) the descending part. In the event the infill masonry is present, but has been ignored, depending upon the value of T of the structure, the base-shear would be over-estimated in case a), remain un-effected in case b) and be underestimated in case c).

Codes of Practice and Infill Panels

IBC and UBC

The US codes such as the International Building Code or its predecessor, the Uniform Building Code, do not include the frames with infill panels, within their list of structural system options.

EN

The Eurocode 8, or EN 1998, covers the seismic analysis and design of frames with infill panels. The standard treats the panels as a dual system, thus utilising the capacity provided by the masonry panels. Section 4.3.6 of the standard provides certain additional checks for ensuring that the hybrid system does not experience a brittle failure.

Building Code of Pakistan

BCP, having been prepared in the image the US codes, does not refer to the system of frames with infill panels.

IS

The Indian Standard IS 1893:2016 covers the analysis and design of frames with infill panels. The standard, under §7.9, prescribes that the panels be modelled as diagonal struts and the system designed for full seismic force.

Discussion

The author prefers the provisions of IS 1893:2016 for use in Pakistan as the construction technology of the two countries is akin to each other.

Modelling of Infill Panels

Various workers have suggested the following widths of diagonal struts for use in the analysis:

Author (year)	Equation
Holmes (1961)	$\frac{w}{d} = \frac{1}{3}$
Stafford Smith (1967)	$0.1 < \frac{w}{d} < 0.25$
Mainstone (1974)	$\frac{w}{d} = 0.175\,(\lambda_h\, h_c)^{-0.4}$

Mainstone (1974) has been adopted by FEMA 356 and IS 1893:2016.

Following are the notations used in the equations above:

w	=	Width of the strut in the model
d	=	Diagonal length of the infill panel
λ_h	=	$\left[\frac{E_m\,(t_m)\,Sin\,(2\theta)}{4\,(E_c)\,I_c\,(h_m)}\right]^{\frac{1}{4}}$
E_m	=	Modulus of elasticity of masonry
t_m	=	Thickness of brick masonry wall
θ	=	Angle of diagonal strut
E_c	=	Modulus of elasticity of column concrete
I_c	=	Moment of inertia of concrete column
h_c	=	Height of column, to beam centerline
h_m	=	Height of infill wall

Summary

In summary, this article suggests that the practice of providing snug-fit infill brick masonry – or even CMU-masonry – panels in concrete framed structures, but ignoring this factor in the analysis is the analysis and design cannot be recommended. The author suggests a rational approach whereby either the said panels are structurally isolated or are included in the designed. Such codes of practice have been identified as provide guidance for including the infill panels in the analysis.

Book Review

Reinforced Concrete Designer's Handbook

Reynold's, Charles, E., James C. Steedman and Anthony J. Threlfall.
Taylor & Francis, New York, 2008

Aqsa Batool[2]

First published in 1932 and revised and reprinted several times, the book under review has come to be known as a classic in the field of reinforced concrete design. As the name suggests, the publication is a handbook and not a text book. Spread over 401 odd pages, the book intends to cover many topics, if not all, encountered by practicing structural engineers using concrete as a material. The hall mark of the book is the manner in which it has been segregated in the light of the problems encountered by the engineers in practice. Divided into 4 parts and 36 chapters, the book is studded by a large number of extremely useful tables.

The book provides extremely useful and handy reference to structural analysis, covering a variety of structures, and also structural design backed by ample number of design aids. The diversity of subjects and topics covered by the handbook, makes it an invaluable storehouse of reference material in a condensed format.

The down side of the book, for some, may initially be its treatment of the subject in the light of European codes to the exclusion particularly of the US standards. In the opinion of reviewer, this aspect does not lower the value of the book on this ground, as a considerable amount of material is generic in nature and extremely useful.

The reviewer feels that this reference is an absolutely necessary part of every structural engineer's library, even he or she generally follows the North American codes.

■

[2] Architectural and Structural Engineer, Rizwan Mirza, Consulting Engineers, Lahore, Pakistan

Biography

Sir Mokshagundam Visvesvaraya

Rizwan Mirza[3]

15th September, 1861 – 14th April, 1962

Diploma in Civil Engineering, College of Engineering, Pune
Honorary Member of ICE

Sir Visvesvaraya was a civil engineer, statesman and the 19th Diwan of Mysore. He was active in the field of water irrigation and designed the Krishna Raja Sagara Dam – a 131 ft high and 8,600 ft long gravity structure with 1.11 maf storage and located in Mandya. The project irrigated barren land and provided drinking water to people of many surrounding cities. Serving British India, he retired as a superintending engineer.

Figure 26: Krishna Raja Sagara Dam

At the request of Nizam of Hyderabad, he was entrusted with the design of flood-protection system for the city of Hyderabad. Visvesvaraya founded the Government and Engineering College, in Karnataka, 1917.

He wrote his memoirs under title of "Memoirs of my Working-Life"

■

[3] CEO, Rizwan Mirza Consulting Engineers, Lahore, Pakistan

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Doctor of Engineering, AIT, Bangkok, Thailand
Senior Advisor to the President, Asian Institute of Technology, Bangkok, Thailand
CEO, CSI, Bangkok Thailand

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