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EXTERNAL LIGHTNING PROTECTION DEVICES : CONVENTIONAL AND NON-CONVENTIONAL APPROACHES

M.Alam* & Y.S.Tomar**

लाइटनिंग से बचाव के परम्परागत सिस्टम में "एयर टर्मिनेशन सिस्टम," डाउन कंडक्टर एवं "अर्थ टर्मिनेशन सिस्टम" का उपयोग किया जाता है। "एयर टर्मिनेशन सिस्टम" में वर्टिकल रॉड्स को उपयुक्त रूप से रखा जाता है और एक साथ बांधा जाता है।

अतः कुछ गैर परम्परागत टाइप के एयर टर्मिनल आ गये हैं। ये एयर टर्मिनल से काफी बड़े क्षेत्र की सुरक्षा का दावा करते है। कुछ मामलों में वे "लाइटनिंग" को रोकने का भी दावा करते हैं। इस लेख में इन दावों के सिद्धांत पर तथा इन दावों के विरूद्ध उठाये गये कुछ प्रश्नों पर विचार किया गया है।

Conventional system for protection from lightning consists of air termination system, down conductor and earth termination system. The air termination system consists of vertical rods placed suitably and bonded together.

Now some non-conventional types of air terminals have come up. These air terminals are said to provide larger protection area. Also in some cases they claim to prevent lightning. This article discusses the theory behind these claims and certain questions which are raised against these claims.

1.0 INTRODUCTION TO LIGHTNING

Lightning is the visible discharge of static electricity within a cloud, between clouds or between the earth and a cloud.

Here we are concerned with the electric discharge between cloud and the structure which we intend to protect.

As a thunder cloud moves over the surface of the earth, an electric charge equal to but opposite the charge of the base of thunder cloud is induced in the Earth below the cloud. An initial path of ionized air known as leader starts from the thunder cloud. The negatively charged leader is generally a stepped leader. These stepped leader appear to only move in quantized steps of approximately 50-100 feet at a time with a 20 to 50 micro second pause between steps. These step leaders propagate towards Earth at a typical average speed of 105 m/second.

When a stepped leader approaches the ground, the presence of opposite charges on the ground enhances the strength of electric field.

The electric field is strongest on ground connected objects whose tops are closest to the base of thunder cloud, such as trees, tall buildings and grounded air terminals. If the electric field is strong enough, a conductive discharge can develop from these points. This discharge is called positive streamer or upward leader. This discharge is due to electrical breakdown of air between the downward negative leader and the tip of the grounded object. These upward leader are initiated when the downward leader is tens to hundreds of meters above the ground.

When upward leader meets the downward leader, a conducting path between the cloud and ground is established. This allows for a much greater current to propagate from the Earth to Cloud. This is the return stroke and most noticeable part of the lightning discharge.

Graphic shows (1) downward leader descending from cloud (left picture); (2)upward streamers emerging from lightning rods and tree (middle picture); and(3) leader-streamer connection (right picture).Source: Uman, M. A. and Rakov, V. A., "A Critical Review of Nonconventional Approaches to Lightning Protection", Bulletin of the American Meteorological Society, December

2.0 CONVENTIONAL SYSTEM FOR LIGHTNING PROTECTION

Conventional systems for lighting protection consist of

- Air terminals
- Down conductor
- Earth Termination

Air terminal is normally a vertical rod (also known as Franklin rod) which intercepts direct lighting strikes to the structure and conduct the lighting current through down conductor to ground through earth termination.

2.1 The Zone Protected By An Air Terminal

To find the zone which is protected by an air

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terminal, a term known as striking distance needs to be defined. The striking distance is defined as the distance from the tip of the downward leader to the object to be struck at the instant that the breakdown electric field is reached across the final gap between the tip of the downward leader and the object. At this point of time an upward leader is initiated from the object to be struck. This striking distance will be more for lightning strikes of higher peak current and less for lighting strikes of lesser peak current.

IEC 62305-3 recommends various striking distances according to various classes of lightning protection system. These are given below :

Class of LPS	Striking distance (meters)
I	20
II	30
III	45
IV	60

NFPA-780 recommends adopting a striking distance of 45m. For plotting the zone of protection due to an air terminal, the rolling sphere method is used. In this method an imaginary sphere of radius equal to the assumed striking distance is rolled across the ground touching the object and air terminal. The points where the rolling sphere touches the ground, object and air terminal can be struck by the lightning and points where the sphere does not touch, can not be.

The Fig.1 shows the zone of protection for a single mast of height H. As can be seen from the figure the zone of protection will be wider for higher values of striking distance for the same height of mast.

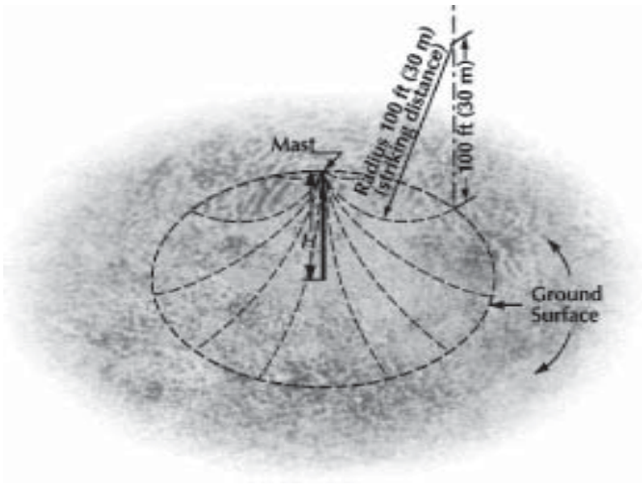


Fig.1 : Zone of protection for a single mast of height H, as determined by the rolling sphere method. Adapted from NFPA 780.

If the height of mast from ground plane increase beyond the striking distance, lightning flashes to the side of the building may occur.

Also in most of the cases only one air terminal will not be able to protect entire top area and top horizontal edges and top corners of the building. Therefore more than one air terminals properly bonded together shall be required.

Other methods for working out zone of protection include the protection angle method.

As defined in IEC 62305-3, In this method, the volume protected by a vertical rod air termination system is assumed to have the shape of a cone as shown in Fig.2.

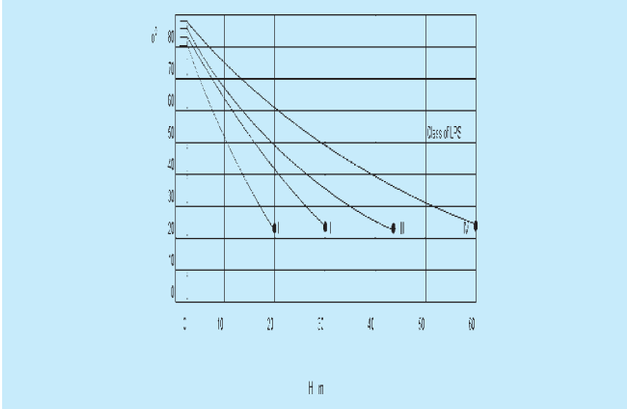
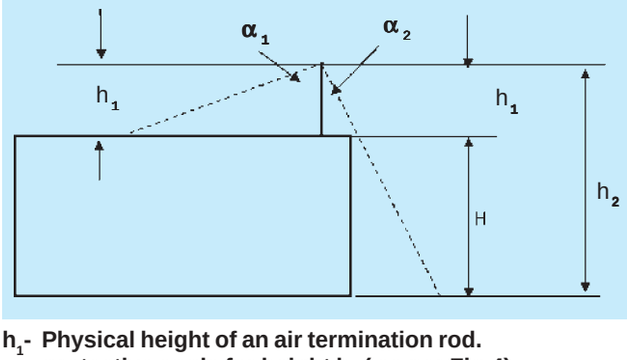


Fig.2

Protective angle as function of h_1 (as per Fig.4) OC- Radius of protected area A- Tip of an air-termination rod h_1- Height of an air termination rod above the reference plane of the area to be protected

The angle α in this Fig. 2 depends on the height of the air terminal from the reference plane and on the class of protection as defined in IEC 62305-1.

This method is again illustrated in Fig.3 for a structure of height H



h_1- Physical height of an air termination rod.
α_1 - protective angle for height h_1 (as per Fig.4)
α_2 - protective angle for height h_2 (as per Fig.4)

(Height h_1 & h_2 are measured from the reference plane of the area to be protected. For h_1, the reference plane is roof & for h_1 the reference plane is earth surface).

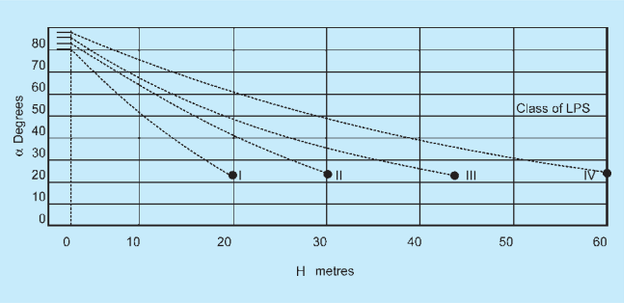


Fig. 4

Protection angle versus mast height. (This is not valid for height of masts beyond striking distances for various classes of protection)

As can be seen from Fig.3., the protection angle **α** is taken different for different heights. It is taken as α_1 for air termination height h_1 ($h_1$being the height above the roof surface to be protected) and it is taken as α_2 for height h_2 (h_2 being the height from the ground being the reference plane.)

The protection angle decreases with the increase is Mast height. The relation between α and Mast height is given in Fig. 4.

As can be seen from the Fig.3 in simple structures also, one air terminal is not sufficient to protect the entire roof. Increasing the height of mast will also not serve the purpose, as the angle α reduces with height. Therefore for proper protection, a system of air terminals is required along with proper bonding. The design of such system is detailed in IEC 62305-3.

3.0 NON-CONVENTIONAL SYSTEMS

There are generally two types of systems which follows non-conventional approach:

- Early streamer Emission Type(ESE Systems)
- Lightning elimination Type (Change Transfer Systems)

3.1 Early Streamer Emission (ESE)

Early streamer emission type of lightning protection system works on the same principle as that of the conventional type system- which is, interception of lightning flashes by air terminal and diverting the lighting current to ground through a system of down conductors and earth terminations. Only difference is that these system employ different type of air terminal.

The air terminal used in ESE systems launches an upward connecting leader earlier than a geometrically similar conventional air terminal would do in the same place.

As a result of this, the upward leader in case of ESE system will meet the downward leader at a greater height. The early launch of upward leader and its meeting the downward leader at a greater height will have the effect of greater striking distance and higher air terminal, there by increasing the zone of protection. This implies that a single ESE air terminal will be able to produce a zone of protection which is produced by many conventional air terminals.

Assuming in ESE system initiation of upward leader takes place Δt seconds earlier than the conventional system and the upward leader travels at the speed of v meter/second, then this time advantage of Δt will be translated into a length/height advantage of

$\Delta L = v\Delta t.$

Assuming Δt = 100 micro second

and $v = 10^6$ m/sec.

ΔL will be 100 meters,

which is a significant advantage over a conventional rod.

3.1.1 Standards

ESE system working principle along with the required high voltage lab tests description, protection radius calculation and installation methods are defined in French standards NFC 17-102:1995.

This standard defines a test procedure for assessing Δt (time advantage as discussed above). In this, the natural lightning conditions are simulated in the high voltage lab, by adding the super imposition of a permanent field representative of ambient field during the storm, and an impulse field, representative of the down-ward leader approaching.

3.1.2 Evaluation of ESE system

The theory of ESE systems is disputed on following points:

- The Spead of upward leader is not 10^6 m/s, but is lower by a factor of more than 10. , therefore the advantage in term of ΔL is reduced by a factor of more than 10, to about 10m which is not a significant improvement.
- Even if it is agreed that the ESE system does indeed launch upward leader at an earlier time which implies at lower electric field as compared to the strength of electric field which would prevail at time of launch of upward leader from conventional air terminal, then the question is raised whether such upward leader will be able to propagate in this lower field.

It is argued that the progression of

upward leader depends upon the supply of energy from the electric field in the space near the tip of leader and upon the dielectric properties of the air which undergoes breakdown. These factors are not influenced by air terminal. Therefore such an upward leader may not propagate very far and may not cause significant improvement in the lightning interception.

- Question are raised regarding lab arrangement specified in the standard NFC 17-102 for testing Δt of ESE devices. It is argued that "it is not likely that one can adequately simulate the natural lightning interception process in a laboratory gap of the order of 2 meter".

3.2 Lightning Elimination Systems or Charge Transfer System (CTS)

3.2.1 Theory

Charge transfer systems consist of an ionizer which is one or more elevated arrays of sharp points. The ionizer is connected to earth termination via down conductors as in case of conventional lightning protection systems.

The protective performance is based on the phenomenon of corona discharge current from the sharp points in an electric field. Under the influence of the electric field of thunder cloud, the ionizer starts to discharge positive charge into the atmosphere, there-by reducing the electric field near the ionizer caused by the negatively charged thunder clouds. This reduced electric field strength makes the lightning discharge path between the tip of the downward lightning leader and charge transfer system, the least preferable one from all other alternatives.

In some cases the build up of the electric field is much faster than the response of charge transfer system, a strong moving upward streamer is formed, which creates the preferable path for lightning discharge into the charge transfer system.

This means that, as compared to conventional rod, the CTS is able to collect lightning strokes from larger area and has therefore bigger zone of protection.

3.2.2 Evaluation

- It is pointed out that trees and blades of grass generate corona discharge, but it does not prevent lightning. However, proponents of charge transfer system say that the charge generated by metallic array of sharp point is much more than that generated by grass or tress. In case of grass or trees the corona discharge is not sufficient to reduce the electric field strength sufficiently to avoid lightning.
- Typical charge carried in lightning discharges is 5 coulomb and time needed to regenerate this charge between lightning discharges is 10 seconds. To neutralize this charge, a corona discharge of 0.5 Amp will be required. As per draft IEEE standard (IEEE P1576/D2.012001) , a 10 point array will produce about 1 mA of corona current, which implies that to produce corona current of 0.5 Amp, the array will require well separated 5000 points. However increase in number of points in array does not increase corona current linearly as the charge produced by one point affects the field at nearby points thereby reducing corona discharge.
- The drift velocity of positive ions generated by corona discharge is low, hence they could not reach the cloud base in timely manner.
- The charge produced will not be stable and will not accumulate over a period of 10 seconds and will be blown away by the horizontal wind.
- Claim of larger protection area, in case charge control system acting to intercept the lightning strike, also disputed on the similar lines as those for ESE system.

4.0 CONCLUSION

- The conventional lightning protection System have proved its effectiveness over the years which is established by comparative statistics of lightning damages to protected and unprotected structures.
- The non-conventional systems were invented in the 1970s and are relatively new. Lightning is not completely understood phenomenon, therefore any claims which are based on theoretical prediction may prove to be false. Further, what ever claims are made by the proponents of non conventional approaches are disputed. The assumption made by the proponents while making the theoretical prediction are questioned on the basis of the observations recorded in field. Also at present there are not many international standards for evaluating the performance of these devices based on nonconventional approaches. There are no IEEE, IEC or NFPA standard for these devices. In case of ESE system there are only French and Spanish standard . In case of charge transfer system, there is a draft IEEE standard IEEE P1S76/D2.01.2001.
- The efficacy of non-conventional approaches can only be proved by experience. Also we can wait for more international standards to come up on these technologies.

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FOUNDATIONS AND FRONTIERS OF QUALITY

Atulya Sinha*

यह लेख गुणवत्ता की विभिन्न परिभाषाओं एवं इस क्षेत्र के विशेषज्ञों के योगदानों से प्रारम्भ होता हैं। इसके बाद गुणवत्ता प्रबंध के मूल सिद्धान्त, ISO 9001 मानक परिवार और भारत में गुणवत्ता प्रबंध का संक्षिप्त विवरण है। अन्त में जीवन के विभिन्न पहलुओं में गुणवत्ता के महत्तव का वर्णन है।

This article begins with various definitions of quality and the contributions of different experts to the field, followed by underlying principles of quality management, an overview of ISO 9000 family of standards and an account of quality management in India. Finally, the importance of quality in different walks of life is briefly discussed.

1.0 WHAT IS QUALITY?

Quality is never an accident.
It is always the result of high intention, sincere effort, intelligent direction and skilful execution; it represents the wise choice of many alternatives.
- William A. Foster

Quality can mean different things to different people. Some widely accepted definitions of quality are fitness for purpose or "conformance to requirements" [1]. A formal definition of quality is "the totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs." [2]

There is a deep-rooted relationship between quality and standardization. While quality is often defined as "conforming to standards", standards can equally well be described as "benchmarks of quality".

Awareness of quality assumed importance with the advent of mass production. The First World War stimulated the development of mass production, and enhanced the importance of inspection and standardization. The Second World War provided another impetus to the development of quality control with a clear emphasis on preventive activities rather than the detection of poor quality. In the decades following the Second World War, Japan was the first nation to recognize and capitalize on the importance of quality and its strategic role in the global market.

In the second half of the twentieth century, the field of Quality was greatly influenced by gurus such as Deming, Feigenbaum, Juran, Crosby, Ishikawa and Taguchi. Some of their teachings are as follows:

- **Edward Deming** focused on problems of variability in quality and in particular on identifying and separating "special causes" of production variability from "common causes". He promoted the use of statistical process control charts as means of controlling quality and removing common causes of variability. Deming is also remembered for his Plan-Do-Check-Act (PDCA) model of quality improvement.
- **Feigenbaum** stressed that quality means "best for customer's use and selling price." Thus, even though a product can meet the customer's functional needs, it must also meet his price requirements.
- **Juran** is best known for his saying that "quality does not happen by chance, it must be planned." Consequently, the requirements or specification of the characteristics of a product or service must be agreed as early as possible.
- **Philip B. Crosby** is noted for saying that doing things right the first time adds nothing to the cost of the product or service [3]. He presented the following four absolutes of quality management:
  - Quality is defined as conformance to requirements, not goodness
  - The system for causing quality is prevention, not appraisal
  - The performance standard must be zero defects, not "that's close enough"
  - The measurement of quality is the price of non-conformance, not indexes.
- **Ishikawa**, the renowned Japanese guru, said that quality does not mean only the quality of the product, but also of after-sales service, quality of management and the human being. His contributions to the field include quality circles, seven QC tools and the QC story.

2.0 FOUNDATIONS OF QUALITY

The underlying concepts of quality management are as follows: [4]

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- ***Measurement***: The process of comparing an unknown against a standard unit with a divided scale was already in use among late Stone Age people. Quantitative knowledge of a particular object helped decide whether the object was useful for a particular task or not. Measurement plays an important role in assessing the usefulness (i.e. quality) of a particular object.
- ***Standardization***: The uniformity of units of weights and measures has been recorded as early as the Babylonian civilization (c. 1800BC). The Romans achieved standardization in many fields and their units of measurement were adopted throughout the empire. This achievement led to measurement becoming a specific component of the production process, particularly in construction works and stone quarrying.
- ***Inspection***: Standardization was initially enforced via inspection and can be traced back to the Roman Empire.
- ***Interchangeable parts***: The invention of printing from movable type is one of the earliest recorded examples of this principle and the Gutenberg Bible printed in 1454 was the first book to be so produced. In Britain, the standardization of component parts and the development of interchangeable mechanisms were developed to a high degree of perfection in the manufacturing of steam engines. The first standardizing authority in the world was established in Britain in 1901.
- ***Precision***: The control of quality necessitates high-precision equipment which can detect any small deviation from the standard. The science of metrology which witnessed rapid progress in the seventeenth and eighteenth centuries and inventions such as the Vernier scale and the screw micrometer contributed substantially to the development of quality control.
- ***Feedback***: Once deviations are detected, they must be fed back and resolved before they become defects.

In recent years, the term "continuous improvement" have gained popularity. However, Collins & Porras point out that this concept has been commonplace for decades in the visionary companies studied by them:

William Proctor and James Gamble, for example, used the concept of continuous improvement as far back as the 1850s. William McKnight brought the concept to life at 3M in the 1910s. Willard Marriott embraced the concept soon after opening his first root beer stand in 1927. David Packard incessantly used the term "continuous improvement" beginning in the 1940s. [5]

It is widely accepted today that quality concepts can be applied to all kinds of goods and services. In the words of management guru Peter Drucker:

"Quality" in a product or service is not what the supplier puts in. It is what the customer gets out and is willing to pay for. A product is not "quality" because it is hard to make and costs a lot of money, as manufacturers typically believe. That is incompetence. Customers pay only for what is of use to them and gives them value. Nothing else constitutes "quality". [6]

3.0 ISO 9000 FAMILY OF STANDARDS

The International Organization for Standardization (ISO) is the world's largest developer of voluntary international standards for business, government and society. Its portfolio comprises more than 18000 standards that provide practical solutions and achieve benefits for almost every sector of economic activity and technology[7]. All the standards are published and periodically revised by ISO after adoptions by the concerned Technical Committee and formal approval by the member bodies.

The ISO 9000 and ISO 14000 families are among ISO's most widely known standards ever. The vast majority of ISO standards are highly specific to a particular product, material, or process. However, the standards that have earned the ISO 9000 and ISO 14000 families a worldwide reputation are known as generic management system standards. "Generic" signifies that no matter what the organization's scope of activity, if it wants to establish a quality management system or an environmental management system, then such a system has a number of essential features for which the relevant standards of the ISO 9000 or ISO 14000 families provide the requirements. "Generic" also means that the same standards can be applied to any organization, large or small, whatever its product or service, in any sector of activity, and whether it is a business enterprise, a public administration, or a government department.

The present ISO 9000 evolved out of BS: 5750. The ISO 9000 family of standards represents an international consensus on good quality management practices. It consists of standards and guidelines relating to quality management systems and related supporting standards. ISO 9001:2008 is the standard that provides a set of standardized requirements for a quality management system, regardless of what the user organization does, its size, or whether it is in the private, or public sector. It is the only standard in the family against which organizations can be certified – although certification is not a compulsory requirement of the standard. The other standards in the family cover specific aspects such as fundamentals and vocabulary, performance improvements,

documentation, training, and financial and economic aspects. ISO 9000 has become an international reference for quality management requirements in business-to-business dealings.

The ISO 9000 family is primarily concerned with "quality management". This means what the organization does to fulfill the customer's quality requirements and applicable regulatory requirements, while aiming to enhance customer satisfaction and achieve continual improvement of its performance in pursuit of these objectives. "Management system" refers to the organization's structure for managing its processes - or activities - that transform inputs of resources into a product or service which meet the organization's objectives, such as satisfying the customer's quality requirements, complying with regulations, or meeting environmental objectives.

ISO 9000 lists eight principles of quality management, which are as follows:

- Customer focus
- Leadership
- Involvement of people
- Process approach
- System approach to management
- Continual improvement
- Factual approach to decision making
- Mutually beneficial supplier relationships

The standard requires the organization itself to audit its ISO 9001:2008-based quality system to verify that it is managing its processes effectively. In addition, **the organization may invite its clients to audit** the quality system in order to give them confidence that the organization is capable of delivering products or services that will meet their requirements. Lastly, the organization may engage the services of an **independent quality system certification body** to obtain an ISO 9001:2008 certificate of conformity. This last option has proved extremely popular in the market-place because of the perceived credibility of an independent assessment. The organization may thus **avoid multiple audits** by its clients, or **reduce the frequency or duration** of client audits. The certificate can also serve as a **business reference** between the organization and potential clients, especially when supplier and client are new to each other, or far removed geographically, as in an export context.

ISO carries out periodical surveys to assess the number of ISO 9001 certificates and the number of countries in which the certified organizations are located. In December 2007, there were 951,486 organizations certified to ISO 9001 globally. [8] The number of certificates held by Indian organizations rose from just 544 in December 2001 to 46,091 in December 2007, representing a growth of about 85 times in a period of six years.

4.0 QUALITY MANAGEMENT IN INDIA

It is the quality of our work that will please God and not the quantity.

- Mahatma Gandhi

Lt.Gen H.Lal, former director general of BIS and a leading authority on quality, comments as follows on the root cause of low quality prevailing in the country before economic liberalization:

Controlled economy and regime of permit and quotas created a situation of shortages in the market. In this environment accent was on quantitative production because almost anything that was produced could be sold due to ever-increasing demand of the consumers. With the absence of domestic competition and virtual ban on imported products, quality and operational efficiency were the major casualties. [9]

According to Krishnamurthy, there have been three phases of quality management in India: [10]

- In the first phase, until the 1980s, the economy was highly regulated and quality was mostly inspection-oriented.
- In the second phase, from 1980s to 2000, quality was recognized as a means to improve customer satisfaction, enhance productivity and reduce cost. Maruti Udyog contributed greatly to the development of a quality culture in the country. During this period, movements like Quality Circles and ISO 9001 were introduced to Indian industry.
- The third phase, from 2000 onwards, represents the maturity of quality management. Some of the significant developments of this period are reduction of tariff barriers and attempts at globalization, which are vital to remaining competitive. Ongoing developments include the advent of TQM practices and the integration of quality techniques such as TQM, TPM, six sigma, lean manufacturing, etc. As economic growth takes place, quality organizations in different sectors of the economy are networking with each other.

4.1 Quality Council of India (QCI)

The nation's apex body for Quality, was set up in 1997 as an autonomous body by the Government of India, jointly with the Indian industry to establish and operate the National Accreditation Structure for conformity assessment bodies. Indian industry is represented in QCI by three premier industry associations, ASSOCHAM, CII and FICCI. QCI is also assigned the task of monitoring and administering the

National Quality Campaign and to oversee effective function of the National Information and Enquiry Services. The Vision of QCI is: *To be among the world's leading national apex quality facilitation, accreditation and surveillance organizations, to continuously improve the climate, systems, processes and skills for total quality.* To realize the objective of improving quality competitiveness of India products and services, QCI provides strategic direction to the quality movement in the country by establishing recognition of India conformity assessment system at the international level. [11]

5.0 FRONTIERS OF QUALITY

One Basic Quality Unites All Works of Mankind That Speak To Us In
Human Recognizable Voices Across The Barriers of Time, Culture And Space:
The Simple Quality of Being Well Made.
- Bill Reid, Canadian folk sculptor

Quality Council of India organizes National Quality Conclaves each year, which attract participants from fields as diverse as academics, defence, government, healthcare, manufacturing, police, quality certification, railways and standardization bodies. While delivering the inaugural address [12] at the Second National Quality Conclave, Dr. APJ Abdul Kalam, then President of India, stressed the importance of quality in all walks of life. He began by saying that India has 6,00,000 villages and 70% Indians live in villages; hence the major areas where quality is required are seeds for farmers, fertilizers, drinking water, medicines and education. Later, Dr Kalam recalled his experiences of developing a quality culture in India's space exploration programme: *Initially, quality was synonymous with inspection of materials, processes and components. From there, we had to conceive concepts of quality control, quality assurance, product assurance, flight readiness and mission readiness*. Dr. Kalam also proposed a National Prosperity Index by combining the GDP with quality of life.

At another National Quality Conclave, the Director General of Rajasthan Police made a presentation [13] on the impact of quality management on his force. They began by identifying problems such as mutual distrust between police and public and lack of community involvement. Consequently, efforts were made to develop trust among general public and instil fear of the law in criminals, by means of police-public partnership programmes, alternate dispute redressal mechanisms and extensive training and counselling of police personnel. Simultaneously, quality management and ISO 9001 certification of police stations were also taken up. The outcomes included upto 90% reduction in crime and reformation of criminals.

While there are immense opportunities for implementation of quality concepts in all walks of life, a wide variety of standards are available today for specialized quality certification. In the food sector, ISO-22000 deals with food safety management systems and attempts to provide certification from "farm to fork". Similarly, organizations dealing with information technology can aspire to ISO-27000 certification for information security management, automobile component manufacturers can obtain ISO/TS 16949 certification and testing & calibration laboratories can get certified to ISO 17025.

In the railway sector, a new global standard known as IRIS (International Railway Industry Standard) has been introduced by UNIFE, the association of the European railway industry. IRIS is supported by operators, system integrators and equipment manufacturers. [14]

The frontiers of quality are continuously expanding.

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FREQUENTLY ASKED QUESTIONS ON WHEEL IMPACT LOAD DETECTOR (WILD)

M.K. Agrawal*, Akhilesh Misra & Ranjana Dhawan*****

आउट आफ राउन्ड पहियों से बहुत अधिक इम्पैक्ट - लोड पड़ता है जिससे आमतौर पर अप्रत्यक्ष क्षति होती है। ऐसे इम्पैक्ट -लोड के अधिक दिनों तक पड़ने से समय से पहले रेल/पहिया बियरिंगें आदि फेल हो सकती हैं। ऐक्सिल लोड में वृद्धि के कारण इस प्रकार की क्षति में भारी वृद्धि होती है। अंतर्राष्ट्रीय रेलों द्वारा ह्वील इम्पैक्ट -लोड डीटेक्टर यानी वाइल्ट सिस्टमों को विकसित करके इस समस्या को हल कर दिया गया है। वर्षों से इन सिस्टमों से रेलों के अनुरक्षण लागत में भारी कमी लाने में सहायता मिली है।

वर्ष 1997 में आरडीएसओ में वाइल्ड सिस्टमों हेतु अनुसंधान कार्य शुरू किया गया था। विश्व बाजार से ऊंची लागत पर वाइल्ड सिस्टमों को खरीदना तथा भारतीय रेलों के लिये यूनीक - ट्रैक स्ट्रक्चर हेतु इस विषय पर अनुसंधान कार्य शुरू किया गया। इसकी डिजाइन का उद्देश्य था एक ऐसा सिस्टम प्रस्तुत करना जिसे कम लागत पर खरीदा जा सके तथा वह चलने में अच्छा हो।

वर्ष 2003 तक इनके प्रोटोटाइप विकसित कर लिये गये थे और भारतीय रेलों के खदान- मार्गों पर इन्हें वर्ष 2007 तक अंतिम रूप से लगा दिया गया था। स्टैंडर्ड इंडस्ट्रियल आटोमेशन सेंसर तथा ओपेन सोर्स साफ्टवेयर के प्रयोग से लागत में काफी कमी लाना संभव हुआ। कॉफमो द्वारा दो बार विश्व निविदा मांगी गयी जिसमें समान आयातित सिस्टम की लागत आरडीएसओ तथा आईआईटी/कानपुर द्वारा संयुक्त रूप से विकसित डिजाइन की लागत से तिगुनी थी।

फील्ड यूनिट द्वारा वर्ष 2007 से इन सिस्टमों के प्रयोग के दौरान बहुत से मुद्दे उठाये गये। इन मुद्दों का अध्ययन किया गया और रिसर्च रिपोर्ट आर-102 (जुलाई-2009) के तहत सिफारिशे जारी की गयी। फिर भी प्रयोग-कर्ताओं द्वारा आमतौर पर पूछे जाने वाले प्रश्नों को हल करने की आवश्यकता अनुभव की गयी।

मुख्य शब्दः - ट्रैक साइड डिटेक्टर, भारतीय रेल, वाइल्ड, वील्ह इम्पैक्ट लोड डीटेक्टर,, वील्ह फ्लैट डीटेक्टर

Out of round wheels produce very high impact loads which result in normally imperceptible damage. Such impact loads sustained over long term leads to premature failure of rail, wheel bearings etc. With rising axleloads, the severity of this type of damage increases. World railways addressed this issue by developing and installing Wheel Impact Load Detectors or WILD systems. These systems, over the years have helped these railways reduce their maintenance cost significantly.

Research for development of WILD systems was initiated at RDSO in 1997. The high cost of procurement of WILD systems from the global market and the unique track structure of Indian Railways initiated the research into the subject. The core design aim was to produce a system with low cost of procurement and ruggedness of operation.

By 2003 prototypes were developed and WILD systems were finally deployed in 2007 on the mining routes of Indian Railways. Substantial cost reductions were possible due to use of standard industrial automation sensors and open source software. Two rounds of global tenders by COFMOW has indicated that the cost of equivalent imported system is more than three times the cost of the design developed jointly by RDSO & IITK.

The field units have raised a number of issues during the use of these systems since 2007. These issues have been studied and recommendations sent under the Research Report R-102 (July 2009). However a need was also felt for addressing the commonly asked questions by the users.

Keywords: Trackside Detectors, Indian Railways, WILD, Wheel Impact Load Detector, Wheel Flat Detector

1.0 INTRODUCTION

Nine numbers of WILD systems have now been in use on the Indian Railways for a period exceeding a year. Each of the systems relay data round the clock. Every train passing causes the system to trigger, capture / analyze and report the condition. The report generated by the system is transferred via internet to the TXR control. It can also be monitored by any authorized personnel through the WILD web site http://www.irwild.net.

RDSO has been in regular touch with the WILD

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users for documenting the problems and suggesting solutions. Deliberation on the issues frequently raised by different Railways is as follows.

2.0 FREQUENTLY ASKED QUESTIONS

Q1. What is WILD?

WILD is an acronym for Wheel Impact Load Detector, which is an unmanned intelligent trackside data acquisition system that measures the dynamic impact load of wheels on the rail.

The system uses strain gauges stuck on the web of the rail to measure the shear strain from which the corresponding shearing load (the wheel load) is determined.

The strain gauges are connected to a data acquisition system which acquires data, computes the values and relays these to the internet based servers.

Q2. What is the need for WILD?

Out of round wheels produce very high impact loads which result in normally imperceptible damage. Such impact loads sustained over long term leads to premature failure of rail, wheel bearings etc. With rising axleloads, the severity of this type of damage increases.

World railways addressed this issue by developing and installing Wheel Impact Load Detectors or WILD systems. These systems, over the years have helped these railways reduce their maintenance cost significantly by identifying the damage causing wheels for quick removal.

WILD systems were developed & deployed on the Indian Railways for the same reason.

Q3. Can WILD detect wheel flats?

No & yes. WILD system is a wheel impact load detector and not a wheel flat detector. The system identifies defective wheels by measuring the vertical impact loads of wheels and identifies wheels which produce high impact load or a high variation in impact load.

Flat wheels cause a higher impact load than a perfectly round wheel and thus can be detected by a WILD system. However, high impact loads are also caused due to many other factors like, wheel out of roundness (types other than wheel flats), wheel humming (vibration of wheel set), homing of suspension, vibration of superstructure, shifted loads and pitting / flats on the sensing rail. Hence a high impact load does not necessarily mean a wheel flat.

However it is also seen that a worn wheel flat has a lesser impact load that a fresh one. The reason as understood on date is that the impact value is determined by the sharpness of the edge of the wheel flat rather than the length of wheel flat. (*Please see paper on this subject under Ref.1*)

Q4. What are the present limits used on WILD for alarms?

WILD measures the impact load value generated by the rolling wheel over two rotations.

Two parameters are calculated i.e. Impact Load Factor (ILF) and Max Load.

The following table shows the present limits of WILD and the action to be taken by the divisional staff.

Max Load		ILF	Flagged As	Action to be taken
20t to 35t (inclusive)	Or	2.0 to 4.5 (inclusive)	Maintenance Alarm	Attention to be given during next scheduled maintenance
>35t	Or	>4.5	Critical Alarm	Attend at the nearest TXR point or detach in station in < 50km

Q5. What is ILF? How is this calculated?

WILD records 12 values of wheel impacts for every wheel that passes over each rail. Thus a total 24 impact values are acquired 12 for left and 12 for the right wheel of one wheel set.

Given the length of the instrumented rail, the wheels in the diameter range of 770 – 1100mm have approximately 2 revolutions over the sensing zones.

Out of the 12 samples the two max samples are removed and the remaining ten are averaged to get the average load of wheel.

The ratio between the max load value to the average load value is called the ILF.

Q6. Why is there a poor correlation between alarms and physical check

High impact wheels are caused by many defects like: eccentricity, discrete defects, periodic non-roundness, non periodic non-roundness, corrugation, roughness, flats, spalling, shelling. Many of these defects are not visually identifiable. (*Please see para 4 of Ref.2*)

The Indian Railways already has in place an efficient system of identifying and removing defective wheels based primarily on visual inspections. This filters out all bad wheels with known and visually identifiable defects. Hence the wheels crossing the WILD systems are highly likely to have the defects which have passed through the visual inspection system. Therefore any wheel identified by a WILD system is very unlikely to have any known or visual defect. Hence a large number of 'cases' of false alarms have been reported

as almost all of the examinations after stopping of trains are visual and the technicians are only looking for known visually identifiable defects.

Many of the defects which can generate high wheel impact loads / high ILF are not presently classified as defects in the regular maintenance instructions presently in use on the IR as these are based on visual inspection of wheel treads. These problems have been seen on the other world railways which have installed WILD systems and this area is still under active research. A research paper by JCO Nielsen and A Johansson (*Out-of-round railway wheels - a literature survey Ref-2*) summarizing these research areas is attached for further information.

Q7. It is seen that WILD systems miss flagging of wagons with known defects. Why does this happen?

These cases happen when WILD does not record maximum load above 35T and ILF not exceeding 4.5. The WILD system alarms are purely based on the vertical load (experienced by the track). WILD system does not flag all defective wheels but only the ones that cross the impact load thresholds (limits) set on the system.

It can also happen when the wheel defect impacts the rail inside a non-sensing zone. This happens when the wheel cannot be fully scanned by the WILD system due to the diametric size. (Please also see the question of wheel diameter and coverage by WILD).

Similar situation occurs if the tread imperfection does not stretch across the full tread, which is true for almost all tread imperfections. Due to the sinusoidal motion of the wheels the rolling contact line changes on the wheel tread and the imperfection will not make contact or make a partial contact thus changing the impact values.

This is a natural limitation of the process of measurement and cannot be addressed by design. Similar results have also been documented in the test reports issued by TTCI (AAR) which state that WILD systems are likely to miss the defects on single pass.

Q8. Are WILD systems capable of scanning wheels of all diameters in range of 770-1100mm?

The present system design of WILD uses 12 channels per rail over a total length of less than 13 meters is optimal for 1000mm wheel dia where 100% coverage is possible. The coverage reduces with change of wheel dia from 1000mm.

Coverage by the WILD system is a function of the inter-sleeper spacing and the number of channels. The inter-sleeper spacing on Indian Railways is presently fixed at 600+/-25mm.

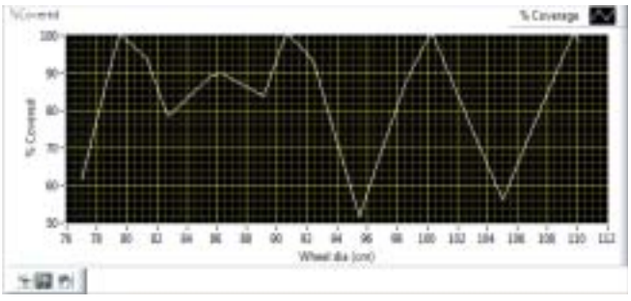

Fig. 1 :Coverage percetage with wheel diameter (12 channel WILD)

Therefore increase in the coverage for all diameters in the range of 770 – 1000mm with the existing strain gauge measurement principle is only possible with increase in number of channels.

However, increasing number of channels is not indefinitely possible due to constraints of cost / complexity and maintenance. Also it should be understood that the increase in wheel coverage is along the contact line only and not the whole surface area of the tread.

The graph in Fig. 1 shows the percentage coverage by WILD as a function of wheel diameter in the range of 770-1100mm.

Q9. Wagons flagged as critical in empty not repeated in loaded

The empty wagons are marked critical only due to the ILF. Under loaded condition, such wheels will be reported if the impact values exceed the limit for maximum load. However since the two criteria are different, there is not an exact equivalence in flagging and such a condition can occur.

Studies done by RDSO have indicated that ILF does not remain a deciding factor at high axle load and high speed as the average value of impact loads increase due to increase in static axle load and also increase in dynamic augment. Hence at higher speeds and heavier loads we find that the ILF follows a decreasing trend.

Q10. Why repeatability of alarms at different speeds is not consistent?

WILD captures data of a real world phenomenon. Although the design of the instrumentation is accurate, the phenomenon of rail wheel contact has probabilistic components e.g. the rolling contact line of the wheel does not remain identical on two consecutive passes, the dynamic forces of other linked structures are also varying in time. As a consequence it is not possible to repeat the result over a finite number of tries.

At higher number of tries, the mechanical wear of wheel defects causes reduction of impact forces as the edges get rounded.

With the added variable of change in speed, the system becomes more complex as the phenomenon of loss of contact results in different impact values at different speeds. (*Please see Ref-1 for understanding the loss of contact phenomenon.*)

Q11. Is there are recommended speed for trains passing on WILD?

Although the system is designed to scan wheels from 30-160kmph, from the trials done by RDSO it can be concluded that best highest probability of defect detection, for the given sets of limits is obtained at speeds of 55-65 kmph.

Q12. The total number of critical and maintenance alarms raised by WILD due to ILF is very high compared to those raised due to wheel max load values. Why is this?

The ILF or the Impact Load Factor is a calculated index with no physical significance. This was invented during the trials of WILD system to flag wheels which are not fully loaded.

The method of calculation of ILF and the present limits make this a very sensitive factor which has been seen to cause a large number of alarms.

Q13. Is anything being done to reduce the number of false alarms by WILD?

RDSO has studied the problem and conducted detailed trials. As a result of these it has been suggested that the present alarm based on ILF should be removed, however the value will continue to be reported for use as a maintenance input and for further research. These suggestions have been presented in the RDSO Research Report R-102 (July 2009)

Removal of alarms based on ILF shall reduce cases of false alarms by a large extent.

Cases of false alarms based high value of wheel impact loads are less frequent. However, at present there are no proposals to modify these limits.

Q14. What are the ramifications of removal of alarms based on ILF?

Removal of ILF as a factor for flagging wheels will reduce the cases of false alarms significantly thus improving the confidence of the maintainers on values reported by WILD.

However, the system shall have reduced sensitivity towards flagging of wheels in less than fully loaded conditions.

This is drawback however does not reduce the effectiveness of WILD in identifying damage causing wheels as these are identified by the high impact load value for which the limits are not changed.

Lightly loaded wheels have a far lower probability of damage to rail and wheel due to impacts, as the value of the maximum impact load is well within the limits of both the rail as well as the wheel.

Q15. I understand that the sensing zone between the sleepers is about 310mm. Does the system read same value of load if applied any where in the sensing zone?

The impact load readings do not change with the point of impact if the points are inside of an influence zone.

Q16. Is there any correlation of number of alarms to the direction of movement of trains?

The system is independent of the direction in which the train runs regarding reporting of alarms. This perception may be caused if there is a significant difference of axleloads of trains running in up / down direction. The direction dependency of the system, incase it is noticed at a site, is a likely result of loaded/ unloaded wagons plying predominantly in one direction.

Q17. Provision for detection of overloaded wagons not available

WILD systems are recording the dynamic load of the wheels. It has been seen that the dynamic load of wheels differ from the static load by 5-30% as a function of speed of the train. The exact value of dynamic augment as a function of speed is not available for the different track conditions of Indian Railways. Additionally there is no provision of correct identification of vehicle type. With these variables it is not possible to accurately classify vehicles as overloaded. Provision of such an alarm at this stage is likely to result in large number of false alarms.

This feature can be implanted only when an accurate relationship between the dynamic augment and speed can be established. This requires extensive trials.

Since the actual axle loads of each individual wagon is available in the detailed report. This can be used to identify overload cases. Doing this automatically through the system is not possible without a supporting technology of automatic vehicle identification.

Q18. Are the present criteria for removal of bad wheels sufficient to handle the alarms raised by WILD?

No. With the development of improved tools the criteria needs to be changed. The present criterion for identification of bad wheels relies heavily on visual observations only, whereas WILD detects the dynamic impact values. There is likely to be good correlation between visual defects and impact values but not the other way around.

This aspect is discussed in *Ref-2* which highlights that more than 50% of high impact wheels do not manifest any visual defects.

Q19. What improvements are being planned to WILD?

WILD is presently capturing data in a snapshot manner. However new research over the world has found that it is possible to use this data for condition monitoring and predictive maintenance.

AAR has created the InteRRIS service which today is a benchmark for use of trackside detectors integrated into maintenance and operations. This now being improved further under the AAR ATSI (Advanced Technology Safety Initiative) Programme as an Equipment Health Monitoring Service (EHMS).

These initiatives require a supporting technology of automatic vehicle identification. RDSO has made a presentation on how the integration of these technologies can convert existing WILD to a condition monitoring tool which can help immensely the maintainers on the field.

Additionally newer designs of WILD are planned for improved wheel coverage with reduction in number of channels for improved scanning at lower maintenance costs.

3.0 CONCLUDING REMARKS

With the experience gathered by the use of WILD on the open lines and considering the data gathered during planned trials, it appears that both the limits and maintenance practices require to be reviewed and modified. However, before these issues are discussed, it is also important to review the best practices of setting up WILD systems and also understand the current research theories of rail wheel interaction.

Strain gauge based WILD systems have been extensively deployed on the US Railroads. AAR has long experience of use of WILD systems. Hence the US railroad experience can be considered to be the 'best practices' benchmark.

Also new research in the field of Rail – Wheel Interaction and the trials conducted by TTCI for setting the limits of the WILD system provide detailed in depth knowledge. These can be used to define guidelines leading to establish correct limits for alarms on the WILD systems.

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SEISMIC ISOLATION OF BRIDGES

R.K. Goel*

तीव्र भूकम्पीय सम्भावना वाले क्षेत्रों में, अपेक्षित भूकम्पनिरोधी पुलों के अभिकल्प के लिऐ भूकम्प विलगन युक्तियों का प्रयोग पुलों की लागत को कम कर सकता है। भूकम्पीय ऊर्जा का तेजी से क्षरण करने के लिऐ भी कुछ युक्तियाँ प्रयोग की जाती हैं, जिससे पुलों में होने वाली भूकम्पीय क्षति को कम किया जा सकता है। पहले से बने हुऐ पुलों में इन युक्तियों का प्रयोग करने से पूर्व, उन पुलों की स्थिति व निर्माण सम्बन्धी जानकारी का समुचित अध्ययन करना आवश्यक है। इस तकनीकी लेख में इसी सम्बन्ध में आवश्यक जानकारी दी गयी है।

Use of seismic isolation devices, for design of railway bridges in seismically critical zones can be made to reduce the cost of construction. Some energy dissipation devices are also used to dissipate the seismic energy efficiently, in order to reduce the structural damages due to earthquake. Proper studies are necessary about the locations and constructional details of existing bridges before these devices are selected for use on existing bridges. This technical paper gives necessary information related with the subject.

1.0 INTRODUCTION

1.1 The traditional method of seismic design of bridges involves estimating seismic demands for design earthquake motion and accordingly the different components of the bridge are designed to provide the requisite strength. The ductile detailing is done in piers or abutments so that they can withstand inelastic deformations during severe earthquakes. The structures are conventionally fixed to the substructure, therefore earthquake motion is transmitted as such.

1.2 There is no attention paid towards decreasing the seismic demand in the traditional approach. As inelastic deformations are permitted, the bridges designed to permit some damage and cracking to non-structural elements such as ballast walls, locations strips of bearings etc. Minor dislocation to superstructure and some misalignment can also be permitted. The conventional construction can cause very high accelerations in stiff piers and large displacements in flexible piers. These two factors cause difficulty in ensuring safety of components.

1.3 A base isolation design is based on innovative concept of decreasing the seismic demand of the bridge by replacing conventional bearings with some kind of isolation bearing, that lengthens its time period and thus reduces transmission of acceleration to the superstructure. Some damping element is also introduced to restrict the amplitude of motion caused by the earthquake. There is a significant reduction in acceleration and displacement at the bearing level, thereby providing protection to superstructure.

1.4 The base isolated bridges are most suitable for important bridges that require higher level of protection. The advantages of seismic isolation include the ability to eliminate or significantly reduce structural and non-structural damage to the bridges and enhance their overall serviceability.

1.5 Some tectonic conditions such as near field earthquakes or soil-foundation condition, particularly soft soil may, however preclude the use of seismic isolation.

2.0 DEVELOPMENTS IN SEISMIC ISOLATION

2.1 The concept of base isolation is not new. The first patent for seismic isolation was taken out in 1909 and since then several proposals have been made to isolate the structure from ground vibrations. Significant development has occurred in rubber technology and sliding systems that have led to the current status of seismic base isolation systems as one of the reliable technique of passive structural control.

2.2 The following developments are responsible for evolution seismic base isolation technique to practical reality:

- Development of high quality elastomeric natural rubber bearings, which can be designed to produce low horizontal stiffness and high vertical stiffness.
- The design and manufacture of mechanical energy dissipators and high damping elastomers that are used to control displacements to acceptable levels and also to resist wind loads.
- The development of computer softwares for analysis of seismically isolated bridges. These softwares can model non-linear behaviour of isolator units.

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- The development of shake table testing techniques to evaluate performance and validate computer modeling.
- The development of techniques of evaluating site-specific parameters of Design Basis Earthquakes.

3.0 BASIC ELEMENTS OF SEISMIC ISOLATION

There are three basic elements in seismic isolation system:

- A flexible mounting between the superstructure and substructure to lengthen the time period.
- A damper or energy dissipater so that the displacement between can be controlled.
- A mechanism to provide rigidity under low lateral loads such as wind or minor earthquakes.

4.0 TYPES OF BASE-ISOLATION SYSTEMS

The most practical devices developed for base isolation of bridges are following:

- Elastomeric bearings
- Lead rubber bearings (LRB)
- Friction pendulum system (FPS)

4.1 Elastomeric Bearings

These bearings consist of thin layers of natural rubber vulcanized and bonded to steel plates. This type of bearing is the most practical form of introducing flexibility into an isolated structure. The vertical rigidity is maintained by steel shims, which are bonded to each layer of rubber. These steel shims constrain lateral deformation of the rubber under vertical load. This results vertical stiffness in bearing of a similar order of magnitude to conventional bearing. A typical elastomeric bearing is shown in Fig. 1a. The natural rubber exhibits a mechanical behaviour which in the simplest description can be represented as a combination of viscoelastic and hysteretic behaviour. Low damping natural rubber bearing exhibits linear elastic and linear viscous behaviour to large shear strains.

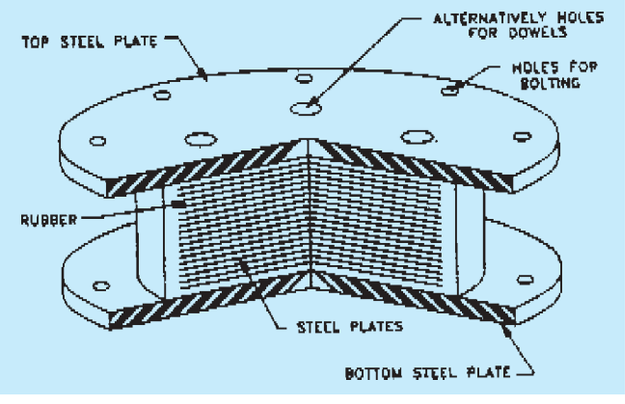

Fig. 1(a)

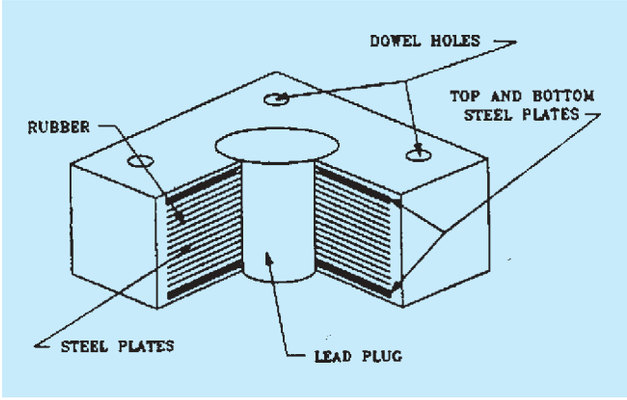

Fig. 1 (b) : Construction of elastomeric bearing

Fig. 2 shows hysteretic behaviour of elastomeric bearing. The equivalent damping ratio is typically less then 0.05 for shear strains in the range of 0 to 200%. High damping rubber (HDR) bearings are made of specially compounded rubber which exhibits equivalent damping ration of 0.10 to 0.20 Fig. 3 shows hysteresis behaviour of high damping rubber bearing.

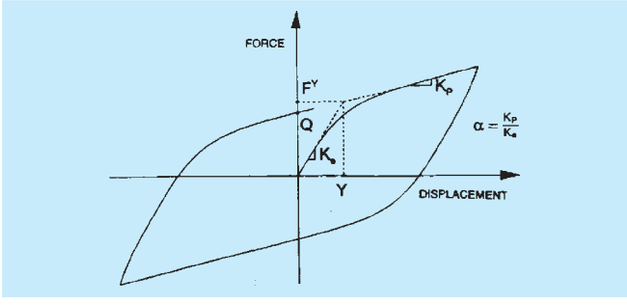

Fig. 2 : Hysteric force-displacement relation of elastomeric bearing

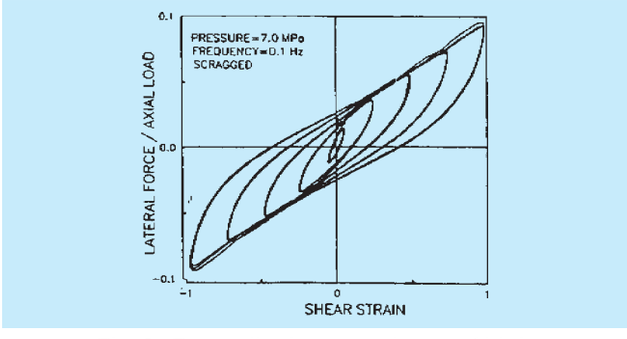

Fig. 3 : Force-displacement loops of high damping rubber bearing

4.2 Lead Rubber Bearing

Lead rubber bearings are constructed of low damping natural rubber with a preformed central hole. A lead core is press-fitted in the hole (Fig. 1b). The lead core deforms in almost pure shear, yields at low level of shear stress and produces hysterisis behaviour, which is stable for a number of cycles. The lead recrystallizes at normal temperature (about 20° C) so that repeated yielding

does not cause fatigue. Lead bearings exhibit characteristic strength, which ensures rigidity under service loads.

4.3 Friction Pendulum System (FPS)

Sliding bearings limit the transmission of force to the isolated structure to a limit of mR. While this is desirable, the lack of restoring force results in significant dispersion in peak displacement response and leads to development of permanent displacements. To avoid these undesirable features sliding bearings should be used in combinations with a restoring force mechanism. The simplest way to introduce restoring force is to provide a spherical sliding surface as in FPS bearings, Fig. 4. The coefficient of friction of sliding bearings depend on a number of parameters of which the composition of sliding surface, bearing pressure and velocity of sliding are most important.

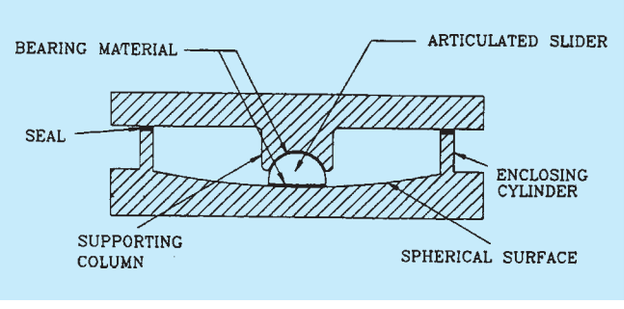

Fig. 4: Construction of friction pendulum (or FPS) bearing

5.0 FORCE REDUCTION DUE TO PERIOD LENGTHENING

5.1 The basic concept in passive base isolation systems is the period lengthening as a result of introducing isolation bearing between super structure and the substructure. The reduction in the force response is illustrated in Fig. 5a. It is dependent on the nature of earthquake motion and period of fixed base structure. Further with the period shift, the displacement across the flexible mount is increased, Fig 5b. However as seen in Fig. 6, the displacement can be controlled by increasing the damping. It is seen that increasing the damping also

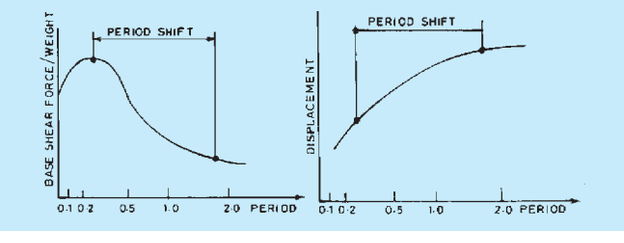

Fig. 5a: Idealized force response spectrum

Fig. 5b: Idealized displacement response spectrum

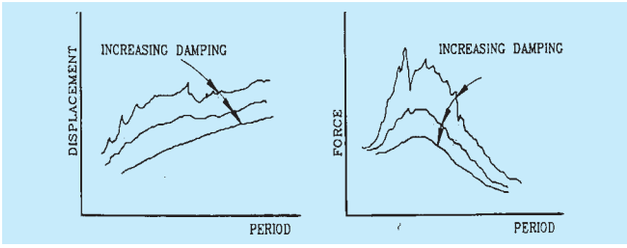

Fig. 6: Response spectra for increasing damping

reduces the forces at given period.

5.2 Care must be taken not to introduce excessive damping into the system because that could produce high accelerations due to higher mode participation in the response.

6.0 ENERGY DISSIPATION

6.1 The most effective way of introducing substantial damping is through hysteretic energy dissipation. The term hysteric refers to the offset in the loading and unloading curves under cyclic loading. Work done during loading is not completely recovered during unloading and the difference is dissipated as heat. Fig 7 shows an idealized force-displacement loop where the enclosed area is a measure of energy dissipated during one cycle of motion.

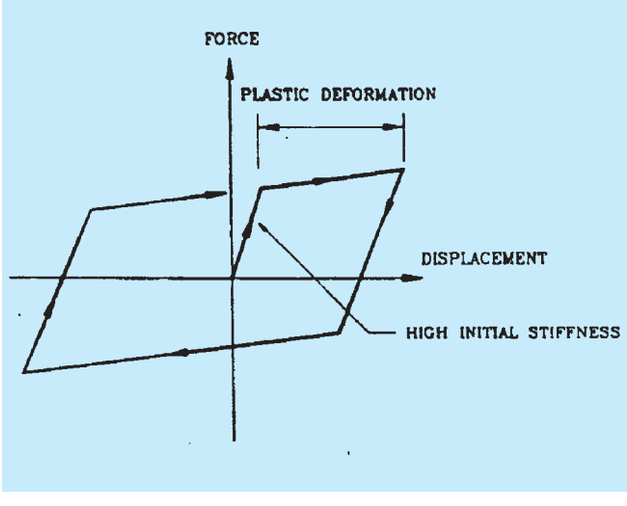

Fig. 7: Hysteretic force-deflection curve

6.2 Several mechanical devices which use friction or the plastic deformation of either mild steel or lead to achieve this feature has been developed in New Zealand are shown in Fig. 8. By addition of special purpose fillers to elastomers it is possible to increase their hysterisis damping without unduly affecting their mechanical properties. So far, it has not been possible to achieve the same level of energy dissipation as is possible with a lead-rubber elastomeric bearing or viscous dampers.

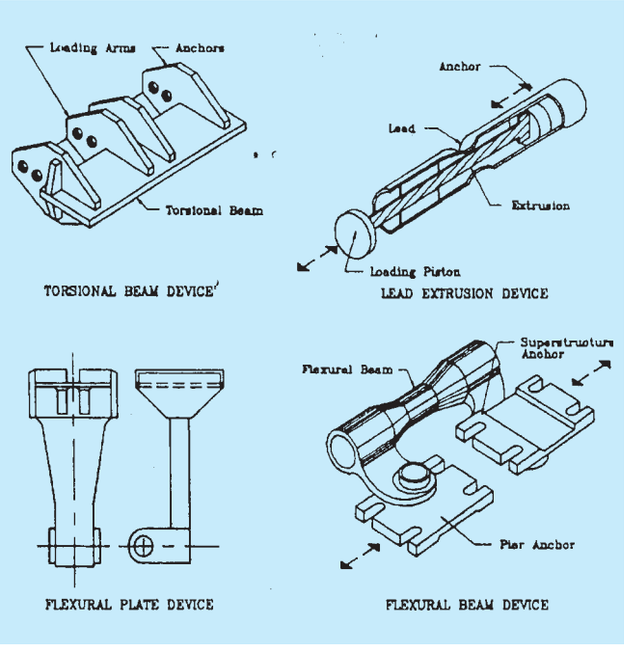

Fig. 8: Various mechanical energy dissipators

6.3 Friction is another source of energy dissipation, which is used to limit deflections. However, with the exception of friction pendulum system, it is a difficult source to quantify. A further disadvantage is that most frictional devices are not self-centering; a permanent offset between the sliding parts may result after an earthquake.

6.4 Hydraulic damping has been used successfully in some bridges. Potentially high damping are possible from viscous fluid flow but the maintenance requirements and high initial cost have restricted the use of such devices. Viscoelastic, friction and shape memory alloys dampers are some more examples of energy dissipation.

7.0 FEASIBILITY OF SEISMIC ISOLATIONS FOR NEW CONSTRUCTION

The bridges are generally suitable for seismic isolations under following conditions:

- The subsoil conditions do not produce a long period ground motion such as occurred in 1985 in Mexico City. The base isolation will not be workable for long period ground motions.
- The most significant benefits obtained from isolation are in bridges for which the fixed base fundamental period of structure is less than 1.0 sec. bridges for which fundamental period is closer to 2.0 sec, base isolation may not be that effective.
- The site permits horizontal displacement at the base of the order of 200mm or more.
- The other consideration when assessing the suitability of a bridge for seismic isolation is soil condition and the geology of site. Generally, stiffer the soil, the more effective the isolation is for soft soil condition, base isolation will not be effective. Another geologic consideration is the distance from a major fault. For near-fault situations, generally the design forces and displacements are amplified so much that base isolation will not be effective.

8.0 FEASIBILITY OF BASE ISOLATION IN RETROFITTING

Retrofit of existing bridges to improve their seismic performance involves additional factors compared to new constructions because of existing constraints. Some bridges are more suitable for retrofit by base isolation than by other methods. For example bridge structures can be retrofitted by replacement of traditional steel bearing with elastomeric bearings. This replacement will cause not only reduction of earthquake-induced forces but allow the redistribution of seismic forces to other regions of structures.

9.0 CONCLUSION

9.1 Design of bridges, based on seismic isolation is an effective and economic solution to reduce the seismic acceleration and displacements in high seismic zones where soil conditions are stiff.

9.2 Use of energy dissipation devices can also be made to control the structural damages due to seismic vibration.

9.3 Retrofitting requirements of existing bridges needs to be studied in detail before using seismic isolation devices to improve their seismic

10. ACKNOWLEDGEMENT

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Instructions for the guidance to the authors in the preparation of articles and other contributions to the Indian Railway Technical Bulletin

To stimulate interest in technical authorship, Railway Board have sanctioned the grant of four annual cash prizes of Rs 2000/-, Rs 1500/- and Rs 1000/- (two numbers) for the article adjudged as first, second and third (two numbers) published in any calendar year in the bulletin and have decided that authors (other than RDSO) of the remaining articles will be paid Rs 400/- for each article depending on its merit.

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Illustrations and photographs should be the minimum required to explain the article. Diagrams and tables should normally be of ISI metric size A4 (297x210 mm) with margins of 13 mm at the top, bottom and right-hand side and 20 mm on the left hand side. Larger diagrams should be on sheets 297 mm deep but should not exceed 420 mm in width as far as possible. In case of diagrams larger than 297x420 mm, lettering should be such that when reduced in size, it remains legible.

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