CHAPTER IV
SPECIALIST APPLICATIONS
FOR ASPHALT MATERIALS
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Chapter IV - Specialist Applications for Asphalt Materials

1. Introduction

In civil engineering the use of asphalt materials throughout the world in highway and airfield applications is well documented. Apart from these major areas within the civil engineering sector requiring the manufacture and performance of high quality asphalt materials, bituminous materials can be used in a variety of other situations. Their ease of modification, either by design or by the inclusion of binder additives to suit a particular application, is considered to be highly advantageous and has led to the development of, what may conveniently be termed, specialist applications. Within the highway industry, many applications have benefited from the introduction of speciality binders. These have generally taken one of two forms; either producing bitumens using special processing routes or by modifying the bitumen with polymers and/or other additives. These options have led to materials that can perform in an increasingly demand-driven market.

Asphalt is also a popular choice for airfields, particularly for runways and taxiways. The development of "friction course" (a porous surface layer) has greatly facilitated the removal of surface water, thereby reducing the risk of aquaplaning. Since its inception, this material has been modified and improved for highway usage and a variety of porous asphalts are now available throughout the world. Environmentalists and politicians have not overlooked the additional benefit of noise reduction. Equally, the successful high-speed applications of thin layers in the highway sphere are being transferred to airport runway applications.

This paper considers the use and benefits from using asphalt in a range of these applications.

2. Binder Specialities

The increasing demands of traffic on road building materials in recent years have resulted in a search for binders with improved performance relative to normal paving grade bitumen. This effort to obtain improved binder characteristics has led to the evaluation, development and use of a wide range of bitumen modifiers which enhance the performance of the basic bitumen and hence the asphalt on the road [1].

Polymers are playing an increasingly important role in the asphalt and bituminous industry because they are able to deliver both performance and durability. Polymers used for bitumen modification in the asphalt paving industry, generally fall in one of two major families: thermoplastic polymers (plastomers) and thermoplastic rubbers (elastomers). Less commonly used are various chemical modifiers and agents, thermosetting systems, fibres and natural additives.

Provide both the type of base bitumen and polymer modifier are carefully chosen to ensure compatibility, incorporating the polymer modifier into bitumen can significantly reduce the temperature susceptibility of the binder in the service temperature range.

In order to obtain maximum benefit from the use of polymer modifiers and to ensure ease of application, it is essential that the polymer modifier systems used do not result in unduly high viscosities at elevated temperatures which could adversely affect the ability to coat the aggregates and to transport, lay and compact the asphalt. This may be achieved by the use of polymer modifiers which, in combination with the chosen type and grade of base bitumen,
exist within the bitumen as a polymer network through thermally reversible bonds in the service temperature range. At application temperatures, these bonds are dissociated, thereby reducing binder viscosity. Both crystalline polymers (e.g. EVA) and thermoplastic rubbers (e.g. SBS) are able to form this type of polymeric network in bitumen.

As a result of the reduced temperature susceptibility of polymer modified binders (PMBs), it is therefore possible to increase the stiffness of the binder at high pavement service temperatures to reduce rutting and at the same time reduce the stiffness of the binder at low pavement temperatures to reduce brittleness and cracking (Figure 1).

The reduced temperature susceptibility resulting from polymer modification can be a key benefit in improving binder performance at both high and low service temperatures. However, it has been found that other properties of the binder may also be improved by the use of suitable polymer modifiers. Fatigue lives of dense asphalt mixes and also thin layers may be significantly increased when PMBs are used.

Improved adhesion to aggregates increased tensile strength and better cohesion of PMBs result in significantly improved performance of surface dressings and thin layers. Polymeric modifiers for bitumen are becoming increasingly used worldwide in applications where enhanced performance of the binder is required to counteract adverse conditions of climate and/or traffic. Due to its complex chemical nature and the interactions between different chemical species in bitumen, there is almost invariably a delicate balance in terms of compatibility between any polymer modifier and bitumen. Achieving this balance depends not only on the accurate selection of grade and chemical composition of base bitumen and polymer modifier but also in the processing conditions used for the production of the PMB.
3. **High Stiffness Bases**

With growing traffic volume and loading, the design considerations used in the past for calculating road thicknesses, are improved. The result, particularly in Western Europe, has been the introduction of much harder grade bitumens for use in the structural layers of the road. The increased stiffnesses obtained have enabled bituminous base layers to successfully compete with concrete. The bitumen industry now has a suite of hard grade binders, including specialities, granted under various Approval Schemes (for example, Avis Techniques) that range from an extremely hard grade of less than 10 penetration units to 10/20, 15/25 and 20/30 grades, with the choice of binder being dependent on the proposed design. Polymer Modified hard grades like PMB 25 are used (e.g. for binder and base courses) on highly stressed pavements like container terminals. In France, these products are now standardised and routinely used.

4. **Porous Asphalts**

Porous asphalt, developed in the 1970s, has become a popular surfacing material throughout the world. The original benefit providing for a draining surface layer, thus reducing spray generation in wet weather, has been complemented by the material's significant reduction in noise generation. Typically, porous asphalts reduce noise levels by up to 5 dB(A), relative to surfacings with a positive texture, which equates to a halving of traffic (in terms of noise). Each country has its preferred porous mixtures ranging from about 6 mm to 20 mm nominal stone size. Laid thicknesses vary from between 15 mm up to 50 mm, depending on the stone size. In the Netherlands, government policy dictates that the national road network should eventually be surfaced with porous asphalt. Porous asphalt is popular in urban environments as its use not only benefits local residents but also minimises the cost of providing additional sound reduction measures (for example, the erection of panelled fencing). In most heavily-trafficked situations, PMBs are the preferred choice in porous asphalts as they have a proven track record in achieving good durability. In Germany, PMBs with a higher polymer content and viscosity are increasingly popular in such applications.

5. **Very thin Layers**

France has a long experience with this kind of bituminous layers. They consist of a gap-graded mix (0/6 or 0/10) with a high content of mastic (filler + binder). The thickness of the layer is between 15 and 25 mm. The voids content being between 9 and 14%, its high macroscopic roughness ensures a very good horizontal drainage of runoff water at the surface. The surface texture is comparable with the texture of a fine SMA (0/6).

The skid resistance is among the best of all pavement surfaces.

Noise reduction of very thin SMA layers is comparable with a freshly laid porous asphalt and usually remains stable during a long time [2].

6. **Bridge Decks**

Bridges pose a particular challenge for the highway engineer in that many of them are subject to thermal movements and, in the case of both concrete and steel decks, must not allow water, and de-icing agents, to affect the structure. There are a number of bituminous options that have been used. Mastic asphalts, and the similar material Gussasphalt, contain high amounts of binder, resulting in a very low air voids content (typically, less than 1 per cent). This makes these materials ideally suited for bridge decks. They may be hand laid (particularly, mastic asphalt) or machine laid and "levelled" to achieve the correct finish.
For the case of steel suspension type bridges, mastic surfacings are ideal in that they:

- Achieve a good bond to the steel deck
- Move with the steel without fatigue problems
- Can accommodate large volumes of canalised traffic.

Where the bridge is subject to large thermal movements, plug joints are often used at either end of the bridge. These transverse joints are relatively wide (up to 600 mm) and comprise a highly polymer modified, very binder-rich mixture, which is able to accommodate the bridge movements.

Mastics have also been used in multi-storey car parks, where the very dense finish protects the car park structure from water ingress. A different interesting use is as an extremely durable thin layer in tunnels, where restricted headrooms are an issue together with limited access for maintenance treatments.

In Germany, Gussasphalt (literally, poured asphalt) has been used for over 40 years on a wide range of major road sites, including both autobahn and city ring roads and specialist equipment is used to pour or lay the material onto the road. The surfacing is extremely rut resistant and durable; however, its initial cost is relatively high compared with other bituminous surfacings. Recently, advances in binder technology have led to lower application temperatures for Gussasphalt on bridge decks. Apart from the advantages during laying of the asphalt, the lower temperature also reduces the likelihood of adversely affecting the underlying sealing layer when used on steel decks.

In France, for bridges in concrete, they sometimes use a special asphalt concrete with a high percentage of modified bitumen at 20 mm thickness. On top of it comes also a special asphalt concrete with modified bitumen too as a wearing course.

7. Fuel-Resisting Asphalts

Fuel and lubricant spillages are known to adversely affect conventional bituminous bound surfacings. When fuel or lubricant comes into contact with asphalt containing petroleum-based paving grade bitumen for a longer period of time, the binder is softened, leading to aggregate loss on the surface. This deterioration can rapidly require the replacement of the asphalt. In locations known for likely fuel spillages, concrete or layers produced with coal tar binders, derived from the destructive distillation of coal, have been used within Europe for fuel resistant applications. However, with tar-based binders, concerns regarding possible adverse effects on health and the environment (including recycling) have led to a rapid decline in their use. Therefore, they are now scarcely, if ever, used.

With the advent of polymer-modified bitumen (PMBs), there has been much effort spent in developing petroleum-based binders that could resist fuel attack. At the same time, detrimental health and environmental effects associated with the tar-based binders are avoided. It should be noted that such binders are currently still more like fuel resisting rather than fuel-proof and thus, in very heavily contaminated areas, concrete will still be the preferred choice. However, certain thermosetting bituminous extended systems have been used in such applications; they can be regarded as fully fuel-resistant. Most likely, further developments in this field will produce more fuel-resistant bituminous binders. There is a wide scope for their use on bus lanes, lorry/car parking areas, bus depots, airport taxiways and parking areas, port and dock loading areas, supermarket delivery areas and other areas where fuels and lubricants are spilled. As far as airport applications are concerned, it has been found that some of the polymer modified binders not only confer a degree of fuel resistance but they
also resist attack from strong chemical de-icers, frequently used in the northern aircraft industry.

8. Motor Racing Circuits

A primary requirement of motor (and motorcycle) racing circuits is their ability to withstand the high shearing and braking forces generated by the race vehicles. The second key requirement is evenness. Asphalt pavements are normally used because they can be laid to a close design specification, an accurate finishing profile and allow for some dispersal of water. Surfacing materials tend to be proprietary in nature and modified binders are typically used. As there is almost no additional compaction through traffic, void contents must be low and binders must resist ageing very well.

The sanctioning body of European car racing (FIA) prescribes asphalt as the surface layer on all Formula 1 Grand Prix tracks. In general, stone mastic asphalt or a tightly specified dense asphalt concrete are used, both containing polymer modified bitumen. More recently, the run-off areas ("gravel traps") are also paved with asphalt to ensure efficient deceleration of cars going off the track.

A racing track in the USA, completed in November 2001, called for a top quality surfacing capable of withstanding cars travelling in excess of 320 km/h. The 12 metre width, 3.5 km length, circuit consists of a surface layer of 50 mm thickness, using a nominal 10 mm grading and a PMB [3]. Given the shape of the track, a paver with manouevrability was employed that enabled the compaction requirement of 98 per cent to be consistently achieved.

9. Railway Applications

In the USA, Far East and various countries within Europe, bituminous materials have been used for a number of years in the construction of railway track beds. The bituminous material may be used in one of four ways:

- To stabilise the aggregate ballast
- As a bituminous bound layer below the aggregate ballast (sub ballast layer)
- As a direct base for the track sleepers (solid railway trackbed)
- As a direct base for the rails

Unbound aggregates used as railway ballast are prone to movement, both lateral and vertical. For normal speed railway rolling stock, such movement is very slight and corrections to levels may be carried out fairly infrequently. Cost considerations have normally precluded the more widespread use of bituminous mixtures in such applications.

However, for the newer rapid transit rail systems (including track to accommodate "tilted" trains) being constructed in many parts of Europe, the stresses imposed by the rolling stock are much higher and greater consideration is being given to the design of the whole railway structure. Bituminous mixtures are now often used in order to "anchor" the rails to the ground and to minimise lateral and vertical movements. In Germany, and elsewhere, different types of sleepers and different systems of fixing the sleepers on the asphalt exist. The perceived advantages are, apart from a better ride quality, better track stability and reduced maintenance [4, 5 and 6].

In Italy [7], the increase in speed, traffic density and load volume has led to the need for a railway superstructure capable of ensuring the constancy of the altimetric layout of the track over the years and limiting the frequency of maintenance to repair sagging. For this purpose, particular attention has been given to studying the behaviour and amount of stress suffered by
the upper part of the railway structure. Over the last few years, the designs of the modern railway structure have evolved to become increasingly similar to those used for busy motorways and airports.

The importance of interposing a connecting layer, mostly either semi-rigid or flexible, between the ballast and railway foundation layers has now been accepted. This layer, known as "sub-ballast", makes a significant contribution to the long-term maintenance of the geometry of the track and must perform at least the following functions:

- Eliminate rainwater from infiltrating the lower layers
- Eliminate high stress loads and consequently, cracks, caused by penetration of stones from the upper layer
- Protect the upper part of the track structure from seasonal freeze-thaw cycles

The Italian State railway has conducted various trials that have led to the inclusion of sub-ballast in the construction of new lines. At present, new lines are constructed using bituminous or mixed cement sub-ballast, depending on the project and building needs involved. The experience gained in the construction of the Rome-Florence line and other sections of the Italian State railway infrastructure led to a comparison and analysis of the advantages and disadvantages in using bituminous and cement-based sub-ballast.

Mixed cement sub-ballast undoubtedly provides a number of advantages, such as:

- Low production costs;
- High quality physical and mechanical characteristics, which tend to increase in time;
- Waterproofing capability

However, the mixed cement solution also has its drawbacks, such as:

- Environmental problems involved in finding the necessary natural aggregates;
- Sensitivity to freezing and the fact that work cannot be carried out below certain temperatures;
- Construction vehicles cannot use the layer until it is hardened;
- The surface of the layer must be protected from adverse weather conditions with bituminous sheets or emulsions.

The advantages of the bituminous mixtures are the following:

- Asphalt is not affected by freezing;
- Asphalt is easily available as production facilities are located throughout the country;
- Asphalt is quick and easy to lay, ensuring that stretches can be laid on a daily basis at a rate of production which halves construction times;
- Asphalt allows for transit of work vehicles very soon to lay the ballast layer;
- A lesser quantity of granular material is required, leading to a saving of approximately 40 per cent in the cost of aggregates in comparison with the mixed cement solution;
- Asphalt performs well with regard to wear and tear;
- Asphalt is suitable for irregular surfaces and adapts easily to any vertical movement without cracking, whilst maintaining its ability to distribute induced stresses;
- Asphalt is waterproof.

10. Hydraulic Applications, including landfill

The waterproofing properties of dense bituminous mixtures (voids contents less than 3 per cent) are well known and, with advances in asphalt technology, these materials have been used in lining reservoirs, canals and dams as well as sea defences and coastal groyne [8]. An interesting and increasing use for asphaltic materials is in the construction of landfill sites.
The two principal properties that make bitumen ideal for such applications are its impermeability and chemical inerterness.

The successful use of asphalt in hydraulic applications such as domestic water reservoirs, fish rearing ponds, and canal liners is well documented. Hot-mix asphalt (HMA) has been used in these applications for more than half a century. Hot-mix asphalt is durable, flexible, and can be designed to be either impermeable or porous. As a quite inert material, it is resistant to the action of most acids, bases and other chemical substances [9].

HMA not only provides a safe environment for fish and drinking water, but it also protects the environment by providing permeable caps for abandoned landfills and deposits of hazardous materials. This diversity of use is illustrated by a three-acre HMA cap on a portion of an abandoned landfill owned by the City of Tacoma, Washington [9].

This cap had to meet stringent permeability standards, sustain heavy axle loads, and be environmentally acceptable. The maximum permeability of $1 \times 10^{-7}$ cm/s allowed by federal and state regulatory agencies was easily attained. The permeability of cores extracted from the completed cap was $9 \times 10^{-10}$ cm/s or less. After the cap was in use one year, a $5 \times 10^{-8}$ cm/s permeability reading was registered. In addition to minimizing the intrusion of surface water into the fill material, the cap serves as the paved surface for a high volume solid waste transfer station.

In Germany, and elsewhere, the deposition of domestic wastes is regulated by government legislation. Thus, landfills must have a lining system at their base, which is resistant to mechanical and hydraulic abrasion as well as impervious against convection and permeation. Comprehensive research work carried out by the Federal Institute for Material Research and Testing (Bundesanstalt für Materialforschung und -prüfung, BAM) has shown that a compound sealing system consisting of a synthetic foil sheet and three layers of clay containing fine mineral aggregates meet the regulatory requirements. Sealing systems produced with other materials, such as dense asphalt concrete, have to be compared with the compound sealing system in order to evaluate whether they can also perform in such landfill environments. The mechanical properties of asphalt are well documented; less certain are the hydraulic abrasion characteristics and the tightness against convection and permeation by hydrocarbon-based solvents.

Work carried out in Germany [10] included a comprehensive laboratory programme on various dense asphalt concrete (AC) mixtures evaluating resistance against hydraulic abrasion and resistance to permeability by both convection and permeation.

In terms of resistance to hydraulic abrasion, even under worst conditions, less than 0.5 per cent of the asphalt concrete was dissolved by the erosive and chemical attack of the solvent during the 14-day period. This shows that a solvent is unlikely to penetrate into the mortar films of well-compacted asphalt concretes for the construction of landfills.

The conclusion is that it should be safe to assume that sufficiently thick layers of asphalt concrete at the bases of landfills would be durable in resisting against attack by aggressive solvents.

In terms of resistance to permeability by convection, in no case, even under the worst case of 10 mm thick mastic asphalt 0/2 under a fluid pressure of 0.5 MPa (i.e. 5 bar) during a period of 24 hours, could a convective permeability be observed. Therefore, it can be assumed that asphalt concrete mixtures with voids contents up to 3.0 per cent are impervious not only against water but also against different aggressive fluids like hydrocarbon-based solvents and salt solutions with basic and acid characteristics.
In terms of resistance to permeability by permeation, the most important results of the tests are recorded for the mastic asphalt 0/2 under the influence of 5 l/m² to 10 l/m² respectively of trichloroethylene during more than 2,000 days.

The overall conclusion is that base sealing systems for landfills for domestic wastes can be built without incurring any environmental risk, provided the asphalt concrete is sufficiently dense and the layer is sufficiently thick. This was reason enough for the German Institute for Structural Engineering to set standards for asphalt concrete as a material for the construction of landfills for domestic wastes in the form of a general building supervisory license [11].

11. Coloured Surfacings and Recreational Areas

A growing trend over recent years has been the development and use of coloured surfacings. These have found a niche market in a variety of situations, ranging from demarcation lanes (for example, cycleways) to aesthetic enhancement of various attractions (for example, amusement parks, parklands and city centres). There are a number of ways in which coloured surfacings can be produced and they include:

- Selection of coloured aggregates
- Selection of coloured fine material
- Selection of translucent, or resinous, binders
- Selection of coloured pigments

A whole range of colours can be produced; the skill is in developing products that retain their colour with time. New assessment methods are being developed to improve this property. Naturally, the surfacings will also need to fulfil other safety and performance requirements, depending on the actual site.

Until recently, there was a very limited range of coloured asphalts available, with red being the predominant colour, but development of specialist binders now permits a much wider colour range. Most coloured treatments are proprietary and require particular care when mixing and laying. It is critical with these mixtures that all forms of contamination are avoided, to reduce risk of discolouration.

Coloured pavements can fulfil several functions [12].

- Alert traffic to special situations (crossings, cycle paths, bus stops, one-way traffic entrance, dangerous factory exits) and different pavement functions, (parking areas, bus lanes)
- Improve the effect of illumination by the use of light coloured surfaces (tunnels, flyovers);
- Increase the attractiveness and status of recreational pavements (tennis courts, playgrounds, park lanes, drives, sports fields – both indoors and outdoors);
- Diminish or enhance the contrast of asphalt with the surrounding soil or vegetation by blending it into the landscape.
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The type of surfacing or pavement selected depends on the traffic type, available materials, and economic considerations. Surface dressing (spray sealing) using coloured aggregates is the most economical coloured surface treatment for lightly trafficked roads and car parks, whilst conventional and translucent binder coloured asphalt provide surfaces more suitable for higher speeds and heavier traffic loads.

Slurry seals can provide a smooth but skid resistant finish over existing pavements and should be considered where there is a requirement for a surface free of loose stone and/or a need to fill minor surface depressions. It is best used for lighter trafficked situations such as housing estate roads, footways, bicycle paths and car parks.

Asphalt surfaces can generally resist scuffing by slow moving turning traffic better than spray sealed surfaces. Coloured asphalt surfaces can be laid in any standard mix design for pavements or driveways. However the consistent texture provided by asphalt of nominal size 5–7 mm or open-graded mixes will give a surface appearance least affected by reflected light.

12. Container Depots

Container ports and depots usually require high strength materials to resist the, often, very high loadings that are applied to the structure. One such example, where asphalt has been used in a novel way is described in [13].

Europe Combined Terminals (ECT), in Rotterdam, is Europe’s largest container terminal. For the past 30 years, pavements of concrete blocks on a (modified) cement treated base (=CTB) have been used. Such pavements proved to be resistant to the heavy loads and torsion forces of the transport vehicles at the terminal. However, with the advent of unmanned automatically guided vehicles (AGV’s), which follow specified tracks (highways), without any lateral displacement, the existing pavements could not take the loads anymore. Severe damage occurred mainly at the locations of guiding pipes (grids) that contain the control cables of the AGV’s present in the CTB.

A number of alternative pavement constructions were considered. Two alternatives with a good price/performance ratio were selected and compared with standard concrete blocks:

- Combination layer (composite of drainage asphalt and cement mortar)
- Asphalt with polymer modified asphalt.

The eventual choice was based on the following criteria:

- Sensitivity to penetration of water into the construction;
- Resistance to increasing weight of AGV’s. In future twin lifting of containers will be applied. The maximum load of AGV’s will increase from 12 tons to 20 tons per wheel;
- Speed of construction of the pavement;
- Maintenance frequency.

The combination layer was composed of four components:

- Drainage asphalt mixture
- Cement mortar
- Combination-layer (composite of drainage asphalt and cement mortar)
- Finishing treatment.

For the drainage asphalt mixture (8/11 gradation), the voids in the drained asphalt were specified to be 25 to 30 per cent. The cement mortar was used to fill the inter-connecting voids in the drainage layer and was specified to be a minimum of 90%.
In the year 2000, approximately 75,000 square metres were paved with the special combination layer; in 2003 it is still performing well.

13. High Skid-resistant Surfacings

Although not an asphalt material, thermosetting binders, containing bitumen extenders are used in high skid-resistant surfacings in some countries, notably in the UK. These binders are normally two-component systems which, when combined in the correct proportions, undergo a thermosetting reaction to irreversibly cure. The binder is applied to the road surface through a specially designed sprayer containing two separate tanks (one for each component) and, upon contact with the road surface, a layer of small-sized high polish-resistant calcined bauxite chippings are applied. Curing of the epoxy-based systems is dependent on temperature, but is usually effected within 3-5 hours.

The resultant treatment, albeit costly at around 15 euros per sq.m, offers an extremely high level of skid resistance and is normally placed over short lengths of road, where the accident risk is perceived to be very high. Typical locations include approaches to road junctions, traffic lights, roundabouts, pedestrian crossings, as well as sharp bends and other places where vehicles are likely to brake or turn severely. In the UK, where such treatments have been laid since the early eighties, it is considered that substantial savings in accidents have been achieved. Research has shown that resin-based anti-skid surfacings result in a reduction of braking distances by up to 33% under wet conditions, in turn reducing wet weather skidding accidents by 67% and total accidents by 31%. The London Accident Analysis Unit has confirmed that 1700 sites treated in one year at a total cost of £3 million yielded an estimated saving of £24 million through accident prevention (Sightgrip, 2002) [14].

Epoxy-resin based bituminous binders have also been used in asphalt surface courses; two that are known of are in porous asphalt and bridge deck surfacings. However, their cost and the potential risk of curing before being laid has precluded their use except in very specific situations.

14. Conclusions

This paper has highlighted the many and diverse ways in which asphalt materials may be used. The number of applications, where bitumen speciality products may be successfully used is extremely wide. Apart from the normally considered highway applications, many other parts of society greatly benefit from bituminous construction materials. Lining of landfill sites and reservoirs through to recreational areas, asphalt plays its part. The ability to produce a whole range of asphalts, which can be application specific and tailored to meet the expected demands, is without doubt one of the reasons bituminous materials are specified and used so widely. Asphalt mixtures ranging from porous, to facilitate spray and noise reduction, to dense, to provide a waterproofing barrier and extremely durable finish, is possibly unparalleled in civil engineering terms. This is due to both the innovations that can be made at the material design stage and the plethora of bituminous binders that may be produced to perform in these specialist applications.
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